Public Health Assessment for

VASQUEZ BOULEVARD AND I-70
DENVER, DENVER COUNTY, COLORADO
EPA FACILITY ID: CO0002259588
MARCH 5, 2002

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

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PUBLIC HEALTH ASSESSMENT

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EPA FACILITY ID: CO0002259588

Prepared by:

Superfund Site Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment-Public Comment Release was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate. This document represents the agency's best efforts, based on currently available information, to fulfill the statutory criteria set out in CERCLA section 104 (i)(6) within a limited time frame. To the extent possible, it presents an assessment of potential risks to human health. Actions authorized by CERCLA section 104 (i)(11), or otherwise authorized by CERCLA, may be undertaken to prevent or mitigate human exposure or risks to human health. In addition, ATSDR will utilize this document to determine if follow-up health actions are appropriate at this time.

This document has previously been provided to EPA and the affected state in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. Where necessary, it has been revised in response to comments or additional relevant information provided by them to ATSDR. This revised document has now been released for a 30-day public comment period. Subsequent to the public comment period, ATSDR will address all public comments and revise or append the document as appropriate. The public health assessment will then be reissued. This will conclude the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Visit our Home Page at: http://www.atsdr.cdc.gov

FOREWORD

The Agency for Toxic Substances and Disease Registry, ATSDR, was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the *Superfund* law. This law set up a fund to identify and clean up our country's hazardous waste sites. The Environmental Protection Agency, EPA, and the individual states regulate the investigation and clean up of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the sites on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by environmental and health scientists from ATSDR and from the states with which ATSDR has cooperative agreements. The public health assessment program allows the scientists flexibility in the format or structure of their response to the public health issues at hazardous waste sites. For example, a public health assessment could be one document or it could be a compilation of several health consultations the structure may vary from site to site. Nevertheless, the public health assessment process is not considered complete until the public health issues at the site are addressed.

Exposure: As the first step in the evaluation, ATSDR scientists review environmental data to see how much contamination is at a site, where it is, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by EPA, other government agencies, businesses, and the public. When there is not enough environmental information available, the report will indicate what further sampling data is needed.

Health Effects: If the review of the environmental data shows that people have or could come into contact with hazardous substances, ATSDR scientists evaluate whether or not these contacts may result in harmful effects. ATSDR recognizes that children, because of their play activities and their growing bodies, may be more vulnerable to these effects. As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable to hazardous substances. Thus, the health impact to the children is considered first when evaluating the health threat to a community. The health impacts to other high risk groups within the community (such as the elderly, chronically ill, and people engaging in high risk practices) also receive special attention during the evaluation.

ATSDR uses existing scientific information, which can include the results of medical, toxicologic and epidemiologic studies and the data collected in disease registries, to determine the health effects that may result from exposures. The science of environmental health is still developing, and sometimes scientific information on the health effects of certain substances is not available. When this is so, the report will suggest what further public health actions are needed.

Conclusions: The report presents conclusions about the public health threat, if any, posed by a site. When health threats have been determined for high risk groups (such as children, elderly, chronically ill, and people engaging in high risk practices), they will be summarized in the conclusion section of the report. Ways to stop or reduce exposure will then be recommended in the public health action plan.

ATSDR is primarily an advisory agency, so usually these reports identify what actions are appropriate to be undertaken by EPA, other responsible parties, or the research or education divisions of ATSDR. However, if there is an urgent health threat, ATSDR can issue a public health advisory warning people of the danger. ATSDR can also authorize health education or pilot studies of health effects, fullscale epidemiology studies, disease registries, surveillance studies or research on specific hazardous substances.

Community: ATSDR also needs to learn what people in the area know about the site and what concerns they may have about its impact on their health. Consequently, throughout the evaluation process, ATSDR actively gathers information and comments from the people who live or work near a site, including residents of the area, civic leaders, health professionals and community groups. To ensure that the report responds to the community's health concerns, an early version is also distributed to the public for their comments. All the comments received from the public are responded to in the final version of the report.

Comments: If, after reading this report, you have questions or comments, we encourage you to send them to us.

Letters should be addressed as follows:

Attention: Chief, Program Evaluation, Records, and Information Services Branch, Agency for Toxic Substances and Disease Registry, 1600 Clifton Road (E56), Atlanta, GA 30333.

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Summary

Background

The Vasquez Boulevard and I-70 (VBI70) site area spans approximately 450 acres in northeast Denver, Colorado and includes smaller areas that the U.S. Environmental Protection Agency (EPA) has proposed to the National Priorities List (NPL). The study area has an irregular shape, and is located primarily southeast of the interchange of Interstate 25 and Interstate 70. It includes all or part of the following five Denver neighborhoods: Clayton, Cole, Elyria, Southwest Globeville, and Swansea. The area is a mix of residential (approximately 17,500 people living in 5,126 housing units), commercial, and industrial areas.

The EPA has taken soil samples from approximately 75% of the residential properties in the VBI70 study area and tested them for several metals, particularly arsenic and lead. This report is about the public health significance of the soil testing.

ATSDR's Findings for Arsenic in Soil

In our daily lives, children and adults ingest small amounts of soil that cling to their hands from what is called hand-to-mouth activity. The amount of soil that people ingest is somewhere around one-sixteenth to one-eighth of a teaspoon. In addition to this inadvertent or accidental soil ingestion, some children, particularly preschool children, will ingest large amounts of soil (for instance, a teaspoon), which is referred to as soil-pica behavior. Generally, this soil-pica behavior occurs in some 1- and 2-year old children as part of their normal exploratory behavior and in some 3- to 6-year old children as part of an intentional behavior. Soil-pica behavior might also occur accidentally when children eat food with dirt adhering to it. The percentage of preschool children (ages 1 through 6) that go through a stage of soil-pica behavior is not known precisely, but studies have reported that this behavior occurs in as few as 4% of children or in as many as 21% of children. One and 2-year old children have the greatest tendency to soil-pica behavior and this tendency decreases as they get older.

ATSDR has determined that soil arsenic levels at many but not all of the properties in the VBI70 study area are safe regardless of how much soil a child or an adult might ingest. ATSDR is concerned about soil arsenic levels in approximately 650 of the 2,986 properties sampled so far. ATSDR is concerned that these properties have arsenic levels in soil that might pose a public health hazard for soil-pica children who ingest unusually large amounts of soil. Based on EPA's baseline risk assessment, EPA has identified properties as a concern for children with soil-pica behavior if the property has an average arsenic level in soil of 47 ppm or greater. Based on demographic information, about 300 preschool children live in these 650 households and somewhere between 12 to 60 of these children might have soil-pica behavior some time during

their preschool years. Depending upon the amount of arsenic contamination in these 650 properties and how much dirt soil-pica children ingest, the most likely health effects that might occur in soil-pica children from eating soil just one time include nausea, stomach cramps, vomiting, diarrhea, facial swelling, and headaches. No children have been diagnosed with arsenic poisoning in the VBI70 area that can be related to arsenic in soil; however, it is possible that cases could have been missed because the most likely symptoms (nausea, vomiting, etc.) are common symptoms in children that can result from a variety of causes.

Arsenic in soil at some properties is also a public health concern for long-time residents because of the potential increased risk of cancer from arsenic exposure. This risk is greatest for children who grew up in yards with high levels of arsenic in soil and who continued to live their as adults. The EPA has identified about 260 properties where the increased risk of cancer is unacceptable. It should be noted that as of spring 2001, EPA has cleaned up about 50 properties so far because of elevated arsenic levels in soil.

Some uncertainty exists in deciding whether or not adverse health effects might occur at the VBI70 site. Uncertainty exists in two areas: estimating how much of a contaminant people are exposed to (that is, the dose) and determining the health effects that might occur. The uncertainty that exists in estimating the dose for soil-pica children comes from the following issues:

- estimating the maximum arsenic level in a property based on the average arsenic level from three composite samples,
- varying amounts of dirt soil-pica children eat,
- variations in how often children exhibit soil-pica behavior,
- assuming that soil-pica children eat soil from the most contaminated part of the property, and
- uncertainty in the percentage of children with soil-pica behavior.

Therefore, a child with soil-pica behavior who lives at a property with arsenic-contaminated soil might not get sick if the child eats soil from an area in the yard with low arsenic levels; or, if the child eats only a small amount of soil, and the amount of arsenic exposure is not enough to cause health effects.

Uncertainty also exists in determining the health effects that might occur because of the inexact nature of the following:

- uncertain estimates of how much arsenic and lead gets into the blood stream and tissues once soil-bound arsenic and lead are ingested,
- assumptions that the harmful effects observed in people exposed to arsenic in drinking water, which is readily absorbed by the body, is similar to the harmful effects that might occur in people exposed to arsenic bound to soil, which is likely to be less absorbed by the body,

- estimates of the dose in human studies when arsenic is found in drinking water, and
- accuracy of the exposure estimates in human studies that were used to develop health guideline values.

ATSDR Findings for Lead in Soil

Some properties in the VBI70 site have high levels of lead in soil that are a health hazard to some preschool children living at those properties. Exposure to lead-contaminated soil at the more highly contaminated properties has the potential for increasing blood lead levels in some preschool children, and might cause harmful effects involving the brain and nervous system. Possible effects include decreased intelligence, developmental delays, decreased stature, altered vitamin D metabolism, changes in blood enzyme levels, and decreased hearing.

EPA has developed a mathematical model that uses the average soil lead levels in a property to predict the percentage of children with blood lead levels above the Centers for Disease Control and Prevention's (CDC) level of concern of 10 micrograms lead per deciliter of blood (μg/dL). For the VBI70 site, EPA's model predicts a range of soil lead levels that could result in more than 5% of the children having blood lead levels greater than 10 μg/dL. The range of soil lead levels predicted by the model vary because EPA varied certain input parameters in the model (specifically, the geometric standard deviation and dietary lead intake). The model predicted that soil lead levels ranging from as little as 208 ppm to as much as 540 ppm as being a concern for increasing blood lead levels in children depending upon which input parameters most accurately predict blood lead levels. It should be noted that 78 properties have average lead levels in soil higher than 540 ppm while about 1,350 properties have average soil lead levels higher than 208 ppm.

Recent blood lead testing by the Colorado Department of Public Health and Environment (CDPHE) in summer 2000 found about 10% of the 86 preschool children tested with blood lead levels above 10 μg/dL. However, it was not possible to determine how much lead contamination in soil contributed to these blood lead levels. Studies by other researchers have shown that about 30 percent of blood lead in children comes from lead in soil. EPA's blood lead model also predicts that a significant portion of a child's blood lead comes from soil. At an average soil lead level of 195 ppm, EPA's model predicts that about 4.4 μg/dL blood lead comes from soil for a typical child. The model predicts that for some children with the highest exposure to lead in soil, their blood lead levels might be as much as 9.5 μg/dL blood lead . It is important to remember that blood lead levels in children are most likely to be the result of exposure to lead from multiple sources. Here are a few examples:

- lead in a child's diet,
- lead in drinking water,
- lead from leaded paint,
- lead in soil,
- indoor dust,
- lead from lead-glazed pottery,
- other unidentified sources.

CDPHE has a state-wide blood lead program that tests children for blood lead. For more information about CDPHE's blood lead program, contact Ms. Mishelle Macias at 303-692-2622. In addition, the Denver Department of Environmental Health (DEH) within the City and County of Denver is responsible for responding to lead issues. DEH's program is managed by Mr. Gene 720-865-5452, who can be contacted at 720-865-5452. DEH follows CDC guidelines, and when a child with elevated blood lead is referred, DEH will conduct an environmental investigation to identify potential sources of lead. Typically, the investigation includes collecting environmental samples from the home environment and administering a questionnaire designed to identify lead sources. DEH also provides the family with information about the health effects of lead, ways to prevent exposure to lead, proper nutrition, access to other relevant services, and the need for follow up blood tests.

Recommendations

ATSDR is making a number of recommendations to address the public health issues concerning arsenic and lead contamination in the VBI70 study area. These recommendations include ATSDR activities, such as developing programs for health care provider education, community education, and health investigations. In addition, ATSDR is making recommendations to local, state, and federal agencies. For instance, ATSDR is recommending to EPA that the agency reduce exposure to arsenic in those properties where soil arsenic and lead levels are a concern for children. ATSDR is also recommending to EPA that the agency collect soil samples from the remaining thousand or so properties in the VBI70 study area. All of ATSDR's recommendations are listed in the Recommendations Section of this report.

ATSDR's Plans for the Future

In addition to the investigations and community involvement activities already conducted by EPA, CDPHE, the City and County of Denver, and ATSDR, ATSDR is planning future activities for the VBI70 site. These activities include the following:

- begin the Agency's environmental health interventions project, a project that focuses on health education for both community members (or residents) and for local health care providers,
- survey residents about soil-pica behavior and other activities that might increase exposure to arsenic and lead in soil,
- identify acute arsenic poisoning in children, and
- consider other health investigations that might be appropriate for the VBI70 site.

ATSDR will continue to work with and assist the community, the City and County of Denver, CDPHE, and EPA throughout our activities at the VBI70 site.

Resumen

Antecedentes

La ubicación del Boulevard Vásquez y la I-70 abarca aproximadamente 450 acres del noreste de Denver, Colorado, e incluye otras áreas más pequeñas que la EPA (Agencia de Protección Ambiental de los EE. UU.) ha propuesto para la Lista de Prioridades Nacionales (NPL). El área estudiada tiene configuración irregular, y se encuentra principalmente al sureste del cruce de la autopista interestatal 25 y la 70. Abarca las siguientes 5 zonas de Denver, total o parcialmente: Clayton, Cole, Elyria, el suroeste de Globeville, y Swansea. El área está compuesta de zonas residenciales (aproximadamente 17,500 personas que viven en 5,126 viviendas), comerciales, e industriales.

La EPA ha recolectado muestras de suelo de aproximadamente 75% de los terrenos residenciales en el área estudiada de la VBI70, y las ha examinado para saber si contienen varios metales, particularmente arsénico y plomo. Este informe trata de la relevancia de la investigación del suelo para la salud pública.

Los Resultados de la ATSDR con respecto al Arsénico en el suelo

En la vida cotidiana, tanto los niños como los adultos ingieren cantidades bajas de tierra que se les afierra a las manos a través de lo que se llama contacto de mano a boca. La cantidad de tierra que ingieren las personas es alrededor de la decimosexta u octava parte de una cucharadita. Además de la ingestión de tierra no intencional, algunos niños, especialmente los de edad preescolar, ingieren grandes cantidades de tierra (por ejemplo, una cucharadita), lo cual es conocido como comportamiento de pica-tierra. Por lo general, este comportamiento de pica ocurre en algunos niños de 1 ó 2 años como parte de su conducta exploratoria normal, y de manera intencional en algunos niños de 3 a 6 años. El comportamiento pica también puede ocurrir cuando los niños comen alimentos con tierra. No se sabe el porcentaje preciso de niños preescolares, o sea los que tienen de 1 a 6 años, que pasan por la etapa de pica, pero los estudios señalan que esta conducta sucede en un mínimo de 4% a un máximo de 21 % de los niños. Los niños que tienen 1 ó 2 años son los que más tienden a exhibir el comportamiento de pica-tierra, el cual disminuye mientras ellos crecen.

La ATSDR ha determinado que el nivel de arsénico en muchos de los terrenos, de la zona estudiada de VBI70, pero no en todos, es seguro sin importar la cantidad de tierra que un adulto o un niño ingiera. A la ATSDR le preocupa el nivel de arsénico en el suelo de aproximadamente 650 de los 2,986 terrenos analizados hasta la fecha. A la ATSDR le preocupa el que estas propiedades tienen niveles de arsénico en el suelo que podrían constituir un peligro a la salud pública en los niños con comportamiento pica que ingieren cantidades anormales de tierra. En base a la evaluación sobre riesgo, la EPA ha calificado las propiedades como preocupantes para los niños con comportamiento de pica-tierra, si la propiedad tiene un nivel de arsénico en el suelo igual o mayor a 47 partes por millón (ppm). En base a la información demográfica, alrededor de 300 niños preescolares viven en los 650 hogares, y entre 12 a 60 de éstos podrían tener comportamiento pica-tierra en algún momento durante los años preescolares. Los efectos a la salud que ocurren con mayor probabilidad en niños con comportamiento pica, debido a la ingestión de tierra en una sola ocasión, y dependiendo de la cantidad de contaminación con arsénico en aquellas 650 propiedades y de cuánta tierra ingieran estos niños, incluyen naúsea, retorcijones, vómitos, diarrea, inflamación de la cara, y dolores de cabeza. Ningún niño de la zona VBI70 ha sido diagnosticado con intoxicación por arsénico, en relación con arsénico en el suelo; sin embargo es posible que no se hayan detectado casos, debido a que los síntomas más comunes en los niños por intoxicación con arsénico (los de vómitos, nausea, etc.), son también síntomas comunes provenientes de otras variedades de causas.

El arsénico en la tierra también constituye una preocupación de salud en algunas personas que llevan mucho tiempo residiendo en el hogar, debido al posible aumento de riesgo de cáncer, por exposición al arsénico. El riesgo es más elevado en los niños que se criaron en patios o jardines con altos niveles de arsénico en la tierra y quienes siguen viviendo allí como adultos. La EPA ha identificado algunos 260 terrenos en los cuales el aumento de riesgo de cáncer no es aceptable. Se debe de notar que en la primavera de 2001, la EPA ya había limpiado alrededor de 50 propiedades debido a los niveles de arsénico en el suelo.

Existen algunas dudas al decidir si han podido ocurrir efectos negativos a la salud en la zona VBI70 o no. Las dudas existen en dos áreas: al estimar la cantidad de contaminante a la cual la gente está expuesta (o sea, la dosis), y al determinar cuáles efectos a la salud pueden ocurrir. La incertidumbre al estimar la dosis en los niños que tienen comportamiento pica-tierra se debe a los siguientes factores:

- estimar el nivel máximo de arsénico en una propiedad basándose en el promedio de los niveles de arsénico en las 3 muestras compuestas,
- cantidades de tierra variables que comen los niños con comportamiento pica-tierra,
- variaciones en la frecuencia con que los niños demuestran comportamiento pica,
- la presuposición de que los niños con comportamiento pica-tierra comen la tierra de la parte del terreno más contaminada, e
- incertidumbre con respecto al porcentaje de niños con comportamiento pica

Por lo tanto, puede que un niño(a) con comportamiento pica que vive en una propiedad con terreno contaminado con arsénico no se enferme, si la tierra que come proviene de un área de la propiedad con un bajo nivel de arsénico, o si el niño solo come una baja cantidad de tierra, y la cantidad de exposición al arsénico no es suficiente para causar daños a la salud.

También existe incertidumbre al determinar los posibles efectos para la salud debido a la índole inexacta de los siguientes factores:

- las estimaciones inexactas sobre cuánto del arsénico y del plomo se integra a la corriente sanguínea y a los tejidos, una vez que se ingiera arsénico y plomo incorporados en la tierra,
- las presuposiciones de que los efectos dañinos observados en la gente expuesta al arsénico a través del agua potable, la cual se absorbe fácilmente en el cuerpo, son semejantes a los efectos dañinos que pueden ocurrir en las personas expuestas al arsénico a través de la tierra, aunque es probable que así se absorba menos al cuerpo,
- los estimados de la dosis en las investigaciones humanas cuando se ha encontrado arsénico en el agua, y
- la exactitud de las estimaciones de exposición en las investigaciones humanas que se utilizaron para establecer las normas de salud.

Los Resultados de la ATSDR con respecto al Plomo en la tierra

Algunas propiedades en la zona VBI70 tienen altos niveles de plomo en el suelo, lo cual constituye un peligro a la salud para los niños preescolares que viven allí. La exposición a tierra contaminada con plomo en los terrenos más contaminados, puede incrementar el nivel de plomo en la sangre de algunos niños preescolares, y puede culminar en efectos dañinos al cerebro y al sistema nervioso. Los posibles daños incluyen disminución de la inteligencia, atrasos en el desarrollo, alteración del metabolismo de la vitamina D, cambios en los niveles de enzimas sanguíneas, y disminución de la audición.

La EPA ha desarrollado un modelo matemático que utiliza el promedio de niveles de plomo en el terreno de una propiedad, para pronosticar el porcentaje de niños con niveles de plomo sanguíneo en exceso a la pauta aceptable establecida por el Centro de Control y de Prevención de Enfermedades (el CDC), la cual es 10 microgramos de plomo por decilitro de sangre (μg/dl). En el caso de VBI70, el modelo de la EPA predice un rango de niveles de plomo en la tierra que podría resultar en que más de 5% de los niños tengan niveles de plomo sanguíneos en exceso de 10 μg/dl. El rango de niveles de plomo en la tierra anticipado por el modelo varía debido a quee la EPA ha variado ciertos parámetros en su cálculo (específicamente, la desviación estándar geométrica y la ingestión de plomo de acuerdo a la dieta). El modelo pronosticó que los niveles de plomo en la tierra en un rango de 208 ppm a 540 ppm, constituyen una preocupación por el incremento de niveles de plomo sanguíneo en los niños, dependiendo de cuáles de los parámetros señalen con más exactitud los niveles de plomo sanguíneos. Se debe notar que el promedio de niveles de plomo en el suelo de 78 de los terrenos, es más elevado que 540 ppm, y en alrededor de 1,350 propiedades es más elevado que 208 ppm.

Análisis sanguíneos recientes realizados por el Departamento de Salud Pública y Ambiental en Colorado (el CDPHE) durante el verano del 2000, descubrieron que aproximadamente 10% de los 86 niños preescolares dieron positivo a niveles de plomo sanguíneos en exceso de 10 μg/dl.

Sin embargo, no fue posible determinar hasta qué punto la contaminación de plomo en la tierra contribuyó a estos niveles de plomo en la sangre. Los estudios de otros investigadores demuestran que aproximadamente 30% de plomo sanguíneo en los niños es consecuencia del plomo en la tierra. El modelo de plomo sanguíneo de la EPA también predice que una parte significante del plomo en la sangre de un niño proviene de la tierra. El modelo predice que si utilizamos como ejemplo un promedio de 195 ppm de nivel de plomo en la tierra, entonces alrededor de 4.4 μg/dl del plomo sanguíneo en el niño normal, proviene de la tierra. Es importante recordar que es probable el que los niveles de plomo sanguíneos en los niños sean la consecuencia de la exposición a plomo a múltiples fuentes. He aquí algunos ejemplos:

- plomo en la dieta del niño,
- plomo en el agua potable,
- plomo proveniente de pintura con plomo,
- plomo en la tierra,
- polvo dentro de la casa,
- plomo proveniente de cerámica con esmalte de plomo,
- otras fuentes no identificadas.

El CDPHE tiene un programa a nivel estatal para examinar los niveles de plomo sanguíneo en niños. Para mayor información acerca del programa de plomo sanguíneo del CDPHE, comuníquese con la Srta. Mishelle Macias al 303-692-2622. Además, al Departamento de Salud Ambiental de Denver (DEH), de la Ciudad y el Condado de Denver, le compete responder a cuestiones de plomo. El programa del DEH es dirigido por el Sr. Gene, con quien se puede comunicar al 720-865-5452. El DEH cumple con las normas del CDC, y cuando se le informe de un niño con plomo sanguíneo elevado, el DEH dirigirá una investigación ambiental para identificar las posibles fuentes de plomo. Normalmente, la investigación incluye el recolectar muestras ambientales del entorno doméstico, y el administrar un cuestionario diseñado para identificar las fuentes de plomo. DEH también provee información a las familias sobre cuales son los efectos a la salud del plomo, cómo prevenir la exposición al plomo, la nutrición adecuada, el acceso a otros servicios relacionados, y la necesidad de análisis de sangre posteriores.

Recomendaciones

La ATSDR está planteando un número de recomendaciones en relación a las preocupaciones de salud pública concernientes a la contaminación de arsénico y plomo en la zona estudiada de la VBI70. Estas recomendaciones incluyen actividades de la ATSDR, tales como el desarrollo de programas de capacitación para proveedores de salud, la educación a la comunidad, e investigaciones de salud. Además, la ATSDR está planteando recomendaciones a las agencias locales, estatales, y federales. Por ejemplo, la ATSDR está recomendando a la EPA que la agencia reduzca la exposición al arsénico en los terrenos en donde los niveles de arsénico y plomo en el suelo son una preocupación para los niños. La ATSDR también le recomienda a la EPA que la agencia recolecte muestras de tierra de los aproximadamente mil restantes terrenos en el área de estudio de la zona VBI70. Todas las recomendaciones de la ATSDR se encuentran en la sección de recomendaciones en este informe.

Los planes de la ATSDR para el futuro

La ATSDR está planeando otras actividades en relación a la zona VBI70, además de las investigaciones y las actividades de incorporación comunitaria ya efectuadas por la EPA, el CDPHE, la Ciudad y el Condado de Denver, y la misma ATSDR. Estas actividades incluyen las siguientes:

- empezar el proyecto de intervenciones en salud ambiental de la agencia, que se enfoca en la educación de salud tanto para los miembros de la comunidad (o residentes) como para los proveedores médicos locales,
- encuestar a los residentes acerca de el comportamiento pica y de otras actividades que podrían incrementar la exposición al arsénico y al plomo en la tierra,
- identificar intoxicación aguda por arsénico en los niños y
- tomar en cuenta otras investigaciones de salud que puedan ser apropiadas para la zona VBI70.

La ATSDR continuará colaborando con, y ayudando a la comunidad, la ciudad y el condado de Denver, el CDPHE, y la EPA, a lo largo de las actividades en la zona VBI70.

List of Acronyms and Abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
AIRS	Aerometric Information Retrieval System
CCC	Cross Community Coalition
CDC	Centers for Disease Control and Prevention
CDPHE	Colorado Department of Public Health and Environment
dL	Deciliter (or 100 milliliters)
DEH	Denver Department of Environmental Health
DNA	Deoxyribonucleic Acid
EPA	Environmental Protection Agency
EKG	Electrocardiogram
ICP	Inductively Coupled Plasma
kg	Kilogram
mg	Milligram
MRL	Minimal Risk Level
NABE	National Association of Black Environmentalists
NPL	National Priorities List
PHA	Public Health Assessment
PHAP	Public Health Action Plan
ppm	Parts Per Million
RGI	Regional Geographic Initiative
RfD	Reference Dose
μg	Microgram
VBI70	Vasquez Boulevard and I-70
VOC	Volatile Organic Compound
XRF	X-ray Fluorescent

Purpose and Health Issues

Purpose

The Agency for Toxic Substances and Disease Registry researches and then writes a public health assessment to evaluate a community's exposure to contaminants at hazardous wastes sites, and then decides what public health activities are needed. This evaluation may involve some or all of the following broad categories of public health activities:

- assessing how people might be exposed to contaminants;
- evaluating possible health effects from exposure to contaminants for a variety of appropriate public health actions;
- recommending medical tests, health education, and health promotion;
- making recommendations to local, state, and federal agencies; and
- finding ways to involve the community in ATSDR's activities.

This public health assessment describes ATSDR's activities at the Vasquez Boulevard and I-70 (VBI70) site and provides what the Agency's opinion is about the public health impact of contamination at VBI70.

In order to investigate this site, ATSDR established the "VBI70 health team," referred to as the health team. Since January 1999, the health team has met regularly to discuss public health issues related to the VBI70 site. Input from team members has been invaluable to ATSDR, and they have helped the Agency evaluate chemical exposures and decide appropriate public health activities. A list of team members appears in Appendix A.

Public Health Issues

During the investigation of the VBI70 site, ATSDR and the health team identified the following public health issues that would be investigated in the public health assessment process:

- Is arsenic contamination in soil a threat to the public's health?
- Is lead contamination in soil a threat to the public's health?
- Is exposure to other chemicals in the environment (e.g., in the air) a threat to the public's health?
- Are communities of color (for example African-Americans or Hispanic people) who live at VBI70 at increased risk of harmful effects from lead and arsenic exposure because of their increased exposure or increased sensitivity?

Site Background

Site Location

The VBI70 site area spans approximately 450 acres in northeast Denver, Colorado (see Appendix B, Figure 1) and includes the area that the U.S. Environmental Protection Agency (EPA) has proposed to the National Priorities List (NPL),[1,2] EPA proposed adding VBI70 to the NPL on January 19, 1999, thus requiring ATSDR to conduct a public health assessment.

As Figure 1 shows, the study area has an irregular shape, and is located primarily southeast of the interchange of Interstate 25 and Interstate 70. The study area does not extend further east than Colorado Boulevard, further south than Martin Luther King Boulevard, further north than 52nd Avenue, and further west than the Burlington Northern rail tracks west of Interstate 25. Figure 3 shows that the VBI70 study area includes all or part of the following five Denver neighborhoods: Clayton, Cole, Elyria, Southwest Globeville, and Swansea. This area includes a mix of residential, commercial, and industrial sections.

Area History

Based on the information that is summarized in this document, there is evidence of contaminated soil in and around the VBI70 study area. Many industrial activities currently take place in and around the study area. In addition, two smelters used to operate and a third smelter still operates in the area. Some information about these smelters follows:

- *The Omaha-Grant smelter.* As Figure 1 shows, the Omaha-Grant smelter was located south of Interstate 70 and west of Brighton Boulevard. The smelter operated at this location from 1882 to 1903. During this time according to government reports, it processed 2,200,000 tons of ore to produce gold, silver, copper, and lead. In 1899, the Omaha-Grant smelter became part of ASARCO, which continued to operate the plant until it closed in 1903. From 1944 to 1950, the Omaha-Grant smelter stack was used intermittently by the City of Denver as a municipal waste incinerator. The City demolished the smelter stack shortly thereafter, covered part of the area with concrete and asphalt, and built the Denver Coliseum on part of the site (Apostolopoulos 1998, ATSDR 1995).

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[1] EPA's NPL is a list of hazardous waste sites that may need some kind of remedial action to reduce exposure to toxic chemicals or radiation.

[2] The boundaries of the the study area shown in Figure 1 are based on maps that EPA provided to ATSDR.

- *The Argo smelter.* As Figure 1 also shows, the Argo smelter was located near the current interchange between Interstate 25 and Interstate 70. This smelter operated from 1879 through 1910 to produce gold and silver by roasting copper ore and matte.[3] The Argo smelter no longer exists.

- *The Globe smelter.* The Globe smelter is located less than 1 mile north of I-70, between Washington Street and I-25. The smelter first began operating in 1886, and was purchased by ASARCO in 1899. The operations at this facility have changed many times over the years. During the time of operations, the smelter has produced gold, silver, copper, lead, cadmium, arsenic, indium, selenium, antimony, and other metals. Current operations at the Globe plant are different from historic operations. Only a few buildings at the plant are currently in use for the production of bismuth products,[4] litharge,[5] highly purified lead, and tellurium.[6] Small amounts of highly purified "specialty metals" are also produced. Specialty metals produced in the late 1990s include cadmium telluride, cadmium sulfide, lead telluride, zinc telluride, and high purity copper cylinders.

Other industrial activities have also taken place in the study area. Those activities are presented in the Regional Geographic Initiative subsection. In addition to industrial activities, arsenic-containing pesticides (for example, herbicides to control weeds) were frequently used in the U.S. during the 1950s and 1960s. The extent to which these sources or activities have affected VBI70 study area soils has not been determined. EPA is currently investigating possible sources of arsenic and lead contamination.

Demographic Information

As part of its investigation, ATSDR considers the number and makeup of the population in the area surrounding a site. For VBI70, ATSDR reviewed the demographic information for different groups of people in the study area:

- *Demographics of the VBI70 study area:* According to 2000 census data, about 17,500 people live in the VBI70 study area—an area with about 5,126 housing units. As shown in Appendix B, Figure 3, the racial composition of the area is diverse:

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[3] Matte is a product that has a sulfur containing metal. Common examples are copper matte and nickel matte.

[4] Bismuth is a metal like lead and arsenic and is used in making pharmaceutical products (for example, Pepto Bismol). It is also used in industrial processes.

[5] Litharge is an oxide of lead made by heating metallic lead.

[6] Tellurium is a nonmetallic element similar to sulfur. It has a number of industrial uses, for example, as part of stainless steel and iron castings as well as a coloring agent in glass and ceramics.

- 5,442 (31%) are white,
- 3,698 (21%) are black,
- 450 (3 %) are American Indian, Alaskan Native, Asian, or Hawaiian, and
- 7,952 (45%) report a race other than those listed in the census.

The "other race" category is so high for the VBI70 study area because many Hispanic people chose this category rather than the other categories of white, black, and other racial groups. In response to a separate question in census, 12,102 people in the study area identified themselves as being of Hispanic origin. Thus, at least 69% of the people in the study area are Hispanic.

Information on potentially sensitive populations, such as young children and older adults, is also presented in Appendix B, Figure 3. Children 6 years old or younger number about 2,400 (14%) of the population, and approximately 1,480 (8%) residents are 65 years of age or older.

- *Demographics of neighborhoods within the VBI70 study area:* Appendix B, Figures 4 through 8, show the same type of population information for each of the five neighborhoods that make up the VBI70 study area: Clayton, Cole, Elyria, Southwest Globeville, and Swansea.

Actions to Reduce Exposure

After sampling soil from about 1,500 yards in 1998, EPA offered to remove soil from the most contaminated properties in the VBI70 study area. This decision was made to prevent residents from coming into contact with soil that contained potentially harmful levels of arsenic and lead. To qualify for time-critical clean-up actions by EPA, properties had to have average soil arsenic levels above 450 parts per million (ppm) or average soil lead levels above 2,000 ppm. Based on the Phase I and II sampling rounds, EPA cleaned up 18 of the 21 properties that had soil contamination above the cleanup levels; owners of the other three properties refused EPA's cleanup offer. As results for Phase III samples came in, EPA removed soil from additional properties that met their criteria.

In response to Phase III soil-sampling results that took place in late 1999 and 2000, EPA has proposed 128 ppm as an preliminary action level for arsenic. About 260 properties in the VBI70 study area exceed this action level. These 260 or so properties have a composite soil sample with arsenic levels greater than 128 ppm. EPA is targeting these approximately 260 properties to protect residents from the risk of cancer. As of summer 2001, about 50 of these properties have been cleaned up by EPA because they met EPA's criteria for time-critical clean-up actions.

During ATSDR's investigations, the agency released a fact sheet about safe gardening practices. The fact sheet included information such as recommendation that residents wash garden produce grown in their yards to reduce the amount of arsenic-contaminated soil that might cling to the produce (See Appendix F for ATSDR's fact sheet on gardening.) In addition, ATSDR released a fact sheet written in English and Spanish that provides easy steps for residents to take to reduce their exposure to arsenic in soil. For example, residents should wash their hands after working or playing outside, wash their dogs periodically, and they should take their shoes off before entering their homes to prevent any arsenic-contaminated soil from being tracked inside. These and other simple steps are described in Appendix I.

Regional Geographic Initiative

In 1989, EPA reported that the Denver zip code 80216, which includes the neighborhoods of Elyria, Southwest Globeville, and Swansea, had the second highest amount of industrial emissions of hazardous pollutants of all Denver zip codes (EPA 1989). This is a trend that has continued in recent years. Industry reports indicate that allowable releases of toxic chemicals to the air, water, and soil in this zip code have increased from 331,000 pounds in 1989 to 771,000 pounds in 1995 (EPA 1995a).

The Cross Community Coalition (CCC), a grassroots community organization located in Swansea, is concerned about these releases and has applied for and received a grant in 1998 from EPA's Regional Geographic Initiative to study local pollution problems. Under this grant, a group of residents, industry representatives, large and small business representatives, a church representative, and staff members from federal, state, and city government have worked together to identify and characterize local sources of pollution and their potential health risks. Some of the CCC's key findings to date follow and are described in detail in Appendix C (Tables C-1 through C-5) and Appendix B (Figure 9):

- The CCC identified numerous emission sources within zip code 80216, such as mobile sources, bakeries, manufacturing facilities, printers, metal shops, vehicle repair shops, refineries, and a major electric power plant that burns low-sulfur coal. These and other sources have been found to emit large amounts of toxic chemicals, and some emit objectionable odors.

- The chemicals released by these sources include, but are not limited to, sulfur oxides, nitrogen oxides, carbon monoxide, particulate matter, organic compounds, and other hazardous air pollutants.

- Four National Priorities List sites are located in or very close to the VBI70 NPL site. These sites are the ASARCO, Inc. Globe Plant, Sand Creek Industrial, Chemical Sales Company, and Broderick Wood Products. Several other industrial operations in the area have special permits from EPA to either generate, transport, or store hazardous waste.

Overall, the findings of the CCC clearly show that many sources of pollution are located in the VBI70 study area. Chemicals released from these sources are likely found at very low levels in many parts of the VBI70 study area, but the exact extent of contamination resulting from these different sources has not been quantified.

ATSDR Activities

ATSDR became involved with the VBI70 site in November 1998. One of the agency's first actions was putting together the VBI70 health team. The health team has planned several public health activities for the site, and has set a schedule for completing them. Some of the activities have been completed. Figure 2 in Appendix B has a timeline regarding the planned ATSDR activities.

ATSDR's public health assessment process—an important activity for the VBI70 site—involves ATSDR evaluating all relevant environmental data, community concerns, and sometimes health outcome data for a site. The information from this first activity is then used to decide what other activities are needed, such as medical testing, health education, and health promotion. The public health assessment for the VBI70 site focuses on evaluating environmental data and community concerns and health education activities that occurred during the investigation. Once decisions are made from evaluating environmental data, community concerns, and medical tests at the VBI70 site, other activities may take place. For instance, as a result of evaluating the extent of arsenic contamination at the site and completing discussions with residents, ATSDR decided to conduct an environmental health intervention project. This involves health education for residents and local health care providers and providing a mechanism for referrals to environmental health clinics for additional medical evaluation, if needed.

ATSDR has released two fact sheets about gardening in the VBI70 study area, has met with residents to discuss gardening issues, has held a national workshop inviting experts to provide advice to the agency about children and adults who eat soil, and will hold public meetings to answer questions concerning this health assessment once it is completed.

Environmental Data

Colorado Department of Public Health and Environment

As a follow up to investigations at the nearby ASARCO Globe Plant Site, the Colorado Department of Public Health and Environment (CDPHE), on July 16, 1997, collected 25 soil samples, three surface water samples, and three sediment samples from what is now the VBI70 study area. The samples analyzed in a lab for levels of inorganic metals, such as, arsenic, cadmium, and lead. The soil samples were collected in Elyria (23 samples) and Swansea (2 samples). Arsenic levels in residential yards were as high as 1,800 parts arsenic for every million parts of soil (ppm) and lead levels as high as 660 ppm (Apostolopoulos 1998; EPA 1998a). The level of arsenic is much higher than expected, which is typically around 7 ppm for Western states (ATSDR 1992). The findings of elevated levels of arsenic and lead prompted EPA to conduct more extensive soil sampling in the five neighborhoods that eventually became the VBI70 study area.

EPA Investigations

The EPA has conducted several environmental investigations at the VBI70 site. This section describes those investigations for this public health assessment.

- *Phase I and II sampling*: In the spring and summer of 1998, EPA conducted what is called "Phase I" and "Phase II" soil sampling at the VBI70 site. During these sampling efforts, EPA collected soils from roughly 1,500 properties in the study area. At each property, EPA generally took two samples of surface soils (from the top 2 inches of soil) and one sample of soil from below the surface (from deeper than 6 inches). These sampling efforts identified many properties with potentially high levels of arsenic and lead in soils.

- *Confirmation sampling*: Based on the results of Phase I soil samples, EPA returned to 55 properties that had some of the highest levels of contamination in order to collect additional soil samples as a "confirmation sampling." This "confirmation sampling" took place as part of Phase II sampling rounds in the summer and fall of 1998. Most of the samples that were collected are called "five-point composite samples," which means that soils from five different locations on a property were collected and mixed together to make a single, composite sample. The confirmation samples' results were used to decide which properties required immediate cleanup. Out of the 55 properties, 21 met EPA's criteria for cleanup. These 21 properties had average arsenic levels in soil above 450 ppm or average lead levels in soil above 2,000 ppm, or both.

- *Intensive sampling*: EPA conducted what is called "intensive sampling" in the summer and fall of 1998 at eight properties. Some of the properties were selected because they had extremely high levels of arsenic or lead in the soils while others were selected because they had low levels of arsenic or lead in the soils. As part of this sampling effort, EPA collected soil samples from the eight selected properties, and from some properties that adjoined the eight focus properties. Using this approach, EPA collected as many as 224 soil samples from each of the eight focus properties. This provided a detailed picture of contamination at those properties. At the adjoining properties, EPA collected soil samples at the shared boundary and up to 15 feet into the neighboring properties. Therefore, the intensive sampling efforts provided information about contamination at the property, at the property line, and into some of the neighboring properties. The results of the intensive sampling effort showed that at properties with elevated arsenic contamination (for example, with several hundred ppm average arsenic levels in soil), the contamination exists throughout the property. One of the intensively sampled properties, however, showed areas of high arsenic contamination and areas of low arsenic contamination.

- *Phase III sampling*: In the fall and winter of 1999 and in spring of 2000, EPA conducted "Phase III" sampling. In Phase III sampling. EPA collected surface-soil samples initially from about 1,550 properties. After this initial effort involving Phase III sampling, EPA continued to collect soil samples from another 1,440 or so properties for a total of 2,986 properties. The first 1,550 or so properties sampled were usually properties that were not sampled in Phases I and II. Many of the 1,440 or so properties that were sampled later in Phase III were properties that had been sampled earlier as part of Phases I and II (EPA 1999b).

  EPA used a different sample design during Phase III to better estimate the average concentration of arsenic and lead at each property. The reason for using an average value to estimate lead and arsenic levels was to better predict long-term exposure. The disadvantage of using an average value, however, it that it usually cannot be used to estimate short-term (or acute) exposures. The new sample design consisted of collecting three composite soil samples from each property, and each composite consisted of 10 individual soil samples. ATSDR used the Phase III data to arrive at most of the conclusions in this public health assessment.

- *Northeast Park Hill sampling*: In a separate action not related to the VBI70 NPL site, EPA provided funds and assistance to the National Association of Black Environmentalists (NABE) to investigate arsenic and lead soil contamination in Northeast Park Hill, a neighborhood east of the VBI70 study area. Working with officials from EPA, CDPHE, and the University of Colorado, NABE collected soil samples in March and August 1999 from 36 residential properties in Northeast Park Hill. ATSDR evaluated these data in order to provide recommendations to EPA that would protect the residents of this neighborhood from exposure to arsenic.

- *Other studies*: In addition to the many soil sampling studies, EPA has also showed how pigs reacted to contaminated soil. Specifically, EPA fed young pigs arsenic-contaminated soil taken from yards in the VBI70 study area to determine how much arsenic the pigs could absorb from their stomach and intestines into their body. EPA plans to use this information to estimate how much arsenic will be absorbed by people who come into contact with arsenic-contaminated soil (EPA 1999c). In other types of tests, EPA conducted studies on the arsenic and lead in soil to determine the chemical and physical form of arsenic and lead that is present in soil (EPA undated).

Environmental Data Results

EPA provided ATSDR with an electronic database of Phases I, II, and III soil sampling data. Phases I and II contained soil measurements from 1,412 properties and consisted of 4,698 records. EPA provided an additional 442 records of confirmation sampling data along with 1,667 records of intensive sampling data from 8 properties. Phase III data contained surface-soil measurements for 2,986 properties.

During all of EPA's sampling efforts, levels of arsenic, lead, and other metals were measured using what is called an "X-ray fluorescent" (XRF) instrument. In addition, 10% of the soil samples were measured using a method called "inductively coupled plasma (ICP) spectroscopy." The ICP measurements were used to check to make sure that the XRF measurements were accurate.

Arsenic in the VBI70 Study Area

According to the XRF results from EPA's Phase I and II soil samples, about 500 properties had at least one soil sample with detectable levels of arsenic in soil. The remaining 900 properties had arsenic levels below the XRF instrument's detection limit, which varied from 44 to 57 ppm. These 900 properties either had background levels of arsenic in their soils (probably around 7 parts per million)[7] or low amounts of arsenic up to the detection of 57 ppm.

A better data set to use is Phase III data, which generally has a detection limit of 11 ppm or below and thus provides more information about low as well as high levels of soil arsenic. Phase III data show that many properties in the VBI70 study area have elevated levels of arsenic. Table 1 in the text that follows shows the number of properties sampled in Phase III at different ranges of arsenic levels in soil. The value of 6 ppm is the lowest level reported. The values of 47 and 128 ppm arsenic are listed because they are levels of concern for children with soil-pica behavior and for cancer, respectively. Using the data from Phase III, which represents 2,986 properties, it is possible to know the magnitude of arsenic contamination for selected arsenic levels in soil. Table 1 shows the range of arsenic levels in soil with the corresponding number of properties in those ranges based on Phase III data. Also presented in Table 1 is the estimated number of

[7] In a survey of U.S. western soils from urban and non-urban areas, the background level was determined to be 7 ppm, with the highest detected level in all samples being 97 ppm (ATSDR 1992).

properties in VBI70 study area that have not been sampled and what would be expected for their arsenic levels in soil. This information is important because it shows that a significant number of properties not test are likely to have arsenic levels in soil that are a health concern for children and adults. For instance, of the 924 properties not tested, about 82 properties are likely to have soil arsenic levels above 128 ppm and about 122 properties will have soil arsenic levels between 47 and 127 ppm.

Table 1

Table1 shows the number of properties in the VBI70 study area at different soil arsenic levels.		
Average arsenic level	Number of properties based on Phase III samples	Estimated number of properties based on the 924 properties not sampled
6 to 46 ppm	2,324	720
47 to 127 ppm	394	122
greater than 128 ppm	268	82
# properties	2,986	924

Legend: parts per million (ppm).

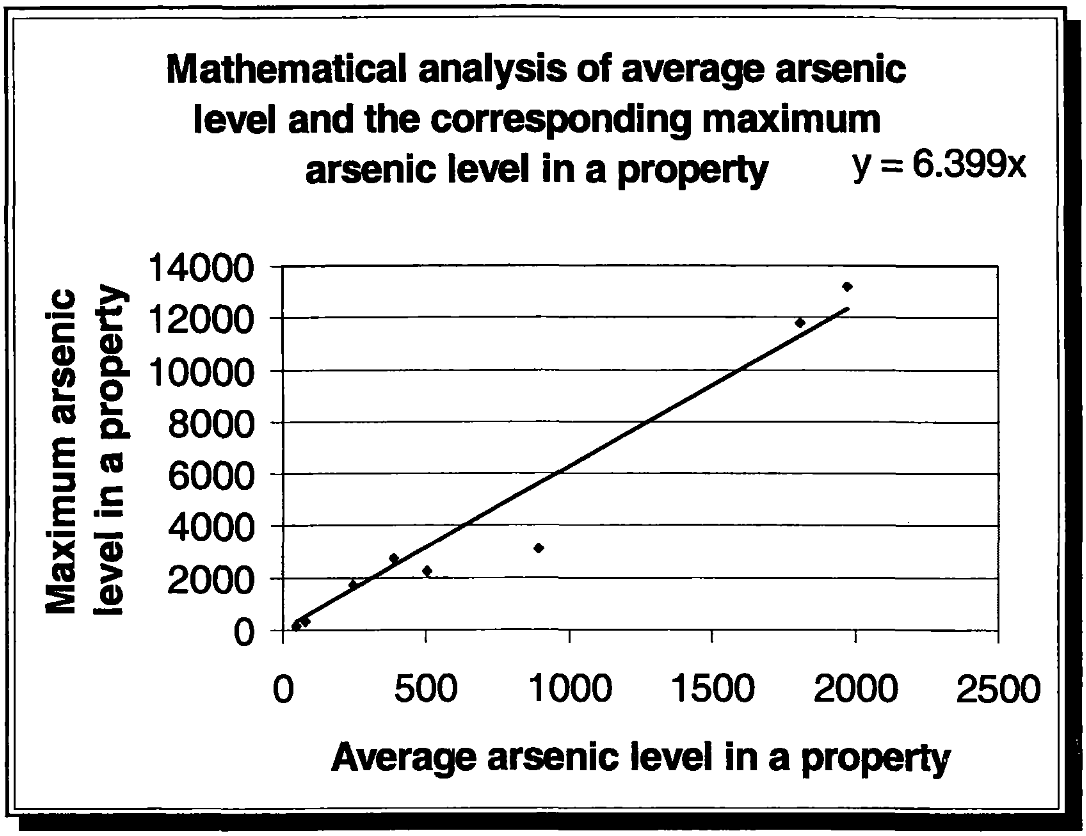
To protect children from exposure to arsenic, it is important to know the highest (or maximum) arsenic level in a yard. The maximum arsenic level can be estimated using information from the eight intensively sampled properties. Graph 1 shows a plot of the average arsenic level and the corresponding maximum arsenic level for the eight intensively sampled properties. The graph shows that as the average arsenic level in a yard increases, the maximum arsenic level in the yard increases in a very predictable way. A very good straight line relationship (as indicated by an r squared value of 0.95[8]) exists between the average soil arsenic level in a yard and the corresponding maximum soil arsenic level for that yard. This straight line relationship allows ATSDR to use Phase III data and the average arsenic level in a property (that is, the average of the three composite samples from a property) to estimate the maximum arsenic level for that yard at a single (discrete) location. The regression formula predicted by the slope is $y = 6.399x$. In other words, this means that the estimated maximum arsenic level in a yard equals 6.399 times the average of three composite samples for that yard.

For example, the highest average arsenic level from Phase III is 759 ppm arsenic. This average of the three composite samples can be multiplied by 6.399 to get an estimated maximum discrete

[8] An r square value of 1.0 indicates a perfect correlation.

arsenic level of 4,856 ppm for that property. Similarly, a property with an average arsenic level of 200 ppm is likely to have an estimated maximum arsenic level in soil of 1,280 ppm. Table 2 shows a range of average arsenic level from various yards and the corresponding estimate of the maximum arsenic level. It is important to note that because only composite samples were collected during Phase III, any mathematical method used to estimate the maximum arsenic level in a property ha some uncertainty associated with that estimate. The true maximum arsenic level might higher or lower. It is reasonable to assume, however, that because of the excellent correlation coefficient that exists using the intensively sampled data, the formula y = 6.399x is probably very close to the true maximum arsenic level.

Graph 1



Environmental investigations by the Colorado Department of Public Health and Environment

Before EPA started collecting soil samples from the VBI70 area, the Colorado Department of Public Health and Environment collected 25 soil samples from Elyria and Swansea in July 1997. Out of 25 properties tested, 12 had elevated arsenic levels, with the highest level being 1,800 ppm (Apostolopoulos 1998).

Table 2

Estimated maximum discrete arsenic levels	
Average arsenic level parts per million (ppm)	Estimated maximum discrete arsenic level using the regression method ppm
759	4,857
600	3,839
500	3,199
400	2,559
300	1,919
200	1,280
150	959
100	640
50	320
30	192
20	128
15	96

Arsenic in the Northeast Park Hill neighborhood

EPA assisted the National Association of Black Environmentalists in collecting two to four individual (discrete) soil samples from 36 residential properties in the Northeast Park Hill neighborhood. Even though the number of samples from each yard is limited, the results show that some properties have elevated arsenic levels in soil. The maximum arsenic level from each property is shown in Table 3.

The limited number of soil samples does not allow ATSDR to evaluate the long-term exposures that might occur from arsenic in soil in this community. However, the high levels of arsenic in some yards can be used to determine the public health implications for arsenic exposure in children who eat soil.

Table 3. Maximum measured arsenic levels in soil at properties in the Northeast Park Hill neighborhood					
Address	Arsenic level	Address	Arsenic level	Address	Arsenic level
Glencoe	1,010	Albion	143	Glencoe	20
Eudora	737	Monaco	78	Glencoe	20
Thrill Place	724	Eudora	58	Glencoe	18
Bellaire	688	Albion	36	Elm	17
Elm	658	Glencoe	36	Thrill Place	17
Dahlia	619	Leyden	32	Fairfax	16
Albion	549	Bellaire	27	Holly	15
Oneida	348	Dexter	26	Glencoe	14
Ash	280	Krameria	26	Holly	12
Hudson	172	Kemey	20	36th Avenue	12
Glencoe	155	Hudson	20	Wheeling	10
Newport	149	Pontiac	20	36th Avenue	10

Lead

EPA's X-ray fluorescent results from Phase I and II soil samples showed that most of the properties contained detectable levels of lead. The typical detection limit for the XRF instruments used by EPA was about 30 ppm, meaning that the instrument usually could not detect lead below that level. That detection limit is close to 20 ppm, the typical background level of lead in naturally occurring soils in the western United States (ATSDR 1992.) It is not unusual, however, for soil in urban and suburban areas to be contaminated with lead at several hundred parts per million. Much of this contamination is due to lead fallout from the past use of leaded gasoline in cars as well as from other sources such as exterior lead-based paint.

Phase III sample results showed that 276 properties had average soil-lead levels above 400 ppm. The highest average lead level in soil based on averaging the three composite samples from a property is 1,131 ppm of lead.

ATSDR has notified Ms. Mishelle Macias with the CDPHE lead poisoning prevention program of the lead levels in soil in the VBI70 study area. Because of the interactions between CDPHE and ATSDR, CDPHE offered blood-lead testing to preschool children in the VBI70 study area through their state-wide lead poisoning prevention program. The results of CDPHE's blood lead investigation are described in the Discussion of Health Outcome Data Section.

Cadmium

During Phase I and II sampling, EPA planned to use XRF instruments to measure cadmium levels in soil. These measurements, however, were often found to be inaccurate. As a result of this problem, EPA has reported that the XRF cadmium measurements from the Phase I and II sampling are not valid.

Although the XRF measurements of cadmium were unsuccessful, EPA sent 363 soil samples from their Phase I investigation to a laboratory for chemical analyses. Those results, which were found to be accurate and valid, show the average cadmium levels from the VBI70 study area to be 5 ppm in surface soil and 5.6 ppm in subsurface soil. The highest level reported was 37 ppm, from a subsurface soil sample (EPA 1998b). These levels are higher than what has been reported as the background level of cadmium in naturally occurring western soil, 0.07 to 1.1 ppm (Kabata-Pendias and Pendias 1984).[9]

While soil cadmium levels appear to be higher than background levels, the level of cadmium in soil will not cause harmful effects to people in the VBI70 study area. The estimated amount of exposure to adults and children from contact with soil is below ATSDR's chronic oral Minimal Risk Level (MRL) for cadmium and below EPA's chronic Reference Dose (RfD) for cadmium.[10] For these reasons, this health assessment report contains no further evaluation of the possibility of harmful effects from cadmium in soil.

Other Contaminants of Concern

Soil contains inorganic metals with a range of naturally occurring levels. Pollution from industrial sources and other types of activity can increase the level of metals in soil. During Phase I, EPA analyzed 44 soil samples for the metals that are most commonly found in soil. Most of these samples came from Swansea and Elyria. Except for arsenic, lead, cadmium, and zinc, the levels of inorganic metals in the 44 soil samples from VBI70 are similar to the levels that are found in soil throughout the western U.S.

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[9] Urban areas often contain higher levels of cadmium because of automobile traffic and possible local industrial sources. A survey by Skyline Labs, Inc., found a geometric average cadmium level in soil of 2.2 ppm in metropolitan Denver (Skyline Labs 1986).

[10] Minimal Risk Levels (MRLs) and Reference Doses (RfDs) are health guidelines designed to identify exposure levels in humans below which harmful effects are unlikely. Please refer to the glossary for more explanation about MRLs and RfDs.

Zinc

The levels of zinc in surface soil at VBI70 ranged from 84 to 1,600 ppm, with an average level of 629 ppm; and the levels of zinc in subsurface soil ranged from 84 to 3,300 ppm, with an average of 406 ppm. These levels are considerably higher than the average level of 65 ppm zinc that occurs naturally in soils in the western U.S. In an earlier site investigation at the ASARCO Globe Plant Site, zinc was also found at elevated levels in soil.

The levels of zinc in soil in the 44 samples are not high enough to cause harmful effects in people. The estimated amount of exposure to zinc for children and adults from contact with soil is below ATSDR's chronic oral MRL for zinc and EPA's chronic RfD for zinc. In addition, zinc is a nutrient, or an essential element for humans. The National Academy of Sciences has recommended that the American diet contain 10 to15 milligrams of zinc per day. For these reasons, this health assessment report contains no further evaluation of the possibility of harmful effects from zinc in soil.

Thallium:

Thallium is another naturally occurring metal in soil. In EPA's Phase I investigation, thallium was detected in the study area at an average level of 13 ppm in surface-soil samples and 15 ppm in subsurface soil samples. Subsequent analysis by EPA using two other methods showed that thallium levels in soil were below 1 ppm and that the XRF instrument was probably overestimating thallium levels in soil. The thallium levels measured by the other two chemical methods are similar to background levels of thallium in naturally occurring soil (ATSDR 1992). These background levels of thallium are not harmful to people. Therefore, thallium will not be evaluated further in this public health assessment.

Adequacy of the Data

ATSDR first reviewed the soil sampling data from different environmental investigations to determine whether the soil sampling data were adequate for making public health decisions. Below is a summary of ATSDR's review of the adequacy of the surface soil sampling data for the VBI70 site.

Phase I and II Samples

During Phase I and II sampling rounds, EPA collected at least three soil samples (two surface and one subsurface) at every property that was considered. The two surface-soil samples characterized levels of contamination at two particular points at each property. They might not provide an accurate measure of property-wide levels of contamination, especially at residences where levels of contamination changed significantly across the property.

In fact, comparison of the Phase I and II data with the more extensive data collected during the confirmation and intensive sampling has showed some significant differences in the levels of contamination at selected properties. This suggests that the Phase I and II sampling did not provide a complete account of soil contamination in some cases.

Intensive and Confirmation Samples

EPA's intensive and confirmation sampling efforts measured contamination in soils at several locations on a property, instead of measuring contamination at just one or two locations. Therefore, these sampling efforts provide a more accurate account of contamination at the VBI70 site. As a result, some of ATSDR's public health decisions for this site were drawn using the intensive and confirmation sampling, and less so from the Phase I and II sampling. More details on this decision follow:

- Intensive sampling: During EPA's intensive sampling, soils were collected at 5-foot intervals at eight residential properties in the VBI70 study area. Additionally, EPA collected soil samples, when possible, as far as 15 feet into the properties that adjoin the eight intensively sampled residential properties. The purpose of the intensive sampling effort was to characterize the distribution of arsenic and lead in both contaminated and non-contaminated yards, and in their adjoining properties. Between 89 and 224 soil samples were collected at each of the eight properties that were included in the intensive sampling effort. Therefore, the intensive soil sampling data are sufficient to make public health decisions for these properties. The limited sampling of adjoining properties does not provide sufficient information to characterize long-term exposure but does provide limited information when evaluating very short-term exposure in children.

- Confirmation sampling: At 55 properties, the EPA collected confirmation samples. As noted earlier, most of the confirmation samples were actually "five-point composite samples," in which soils from five locations were gathered and analyzed as one sample. A composite sample was collected from the back yard and front yard of every property considered in this sampling, and discrete soil samples were collected in selected side yards and gardens. Therefore, the confirmation sampling effort characterized levels of contamination at many locations at each property, thus providing a useful indicator of the property-wide contamination. Figures 21 and 22 in Appendix B show examples of intensively sampled properties.

- Intensive versus confirmation sampling: It should be noted that five properties were part of both the confirmation and intensive sampling efforts, enabling ATSDR to compare the results for these two sampling approaches. In general, the two sampling schemes provide somewhat similar results. There are some exceptions, which show that the intensive sampling scheme provides a better estimate of property-wide contamination than the 5-point composite scheme. Because five-point composites might miss significant areas of contamination, the confirmation results are less reliable in making public health decisions compared to the intensive sampling.

Phase III Soil Samples

Phase III soil sample results were generated by collecting three 10-point composite samples from each property. This sample design will be sufficient for making public health decisions about long-term exposure to contaminants in soil. Because ATSDR was able to estimate the maximum arsenic level in soil from the average level determined by the composite samples, the agency will also use the Phase III data to determine the health hazard of very short-term exposure to arsenic in soil. In ATSDR's discussions with EPA officials in the development of Phase III sample design, EPA agreed to use Phase III data to decide which properties should be resampled because of possible high areas of arsenic contamination.

Air Data

The Aerometric Information Retrieval System (AIRS) is a publicly accessible database of information about air pollution in the United States. EPA has many uses for AIRS, but the database's main use is to track changes in air quality across the country. The information in AIRS comes primarily from states which are required to submit air quality measurements to EPA for certain pollutants. The state of Colorado routinely provides summaries of its air quality measurements to EPA, and these results are then loaded in AIRS. Currently, AIRS has extensive air quality data for more than 20 ambient air monitoring stations throughout the Denver metropolitan area, thus providing extensive information about this area's air quality for certain pollutants.

According to EPA, air quality throughout the Denver metropolitan area currently meets the federal criteria for lead, nitrogen dioxide, and sulfur dioxide. In the past, Denver County and parts of Adams County were not in attainment with EPA's National Ambient Air Quality Standard for particulate matter and carbon monoxide. ATSDR has been informed by staff from the Denver Department of Environmental Health that Denver currently meets EPA's Ambient Air Quality Standard for particulate matter and carbon monoxide.

Technically, the 1-hour standard for ozone has not applied to the Denver metropolitan area since May 1998. Prior to 1998, Denver County and parts of Adams County were not in attainment with the 1-hour ozone standard. ATSDR has been informed by staff from the Denver Department of Environmental Health that Denver currently meets EPA's Ambient Air Quality Standard for particulate matter and carbon monoxide.

Discussion of Exposure Pathways

Completed Exposure Pathways

One of ATSDR's first goals is to identify "exposure pathways." Exposure pathways are different ways that contaminants move in the environment and the different ways that people can come into contact with chemicals, such as breathing them in (inhalation) or accidentally drinking or eating them (ingestion). A "completed exposure pathway" exists when information shows that people have come into contact with a contaminant in soil, water, or air. Completed exposure pathways can be either in the past, the present, or could be in the future. ATSDR has identified two completed exposure pathways for the VBI70 site, as described below.

Soil Ingestion in children and adults

The most significant exposure pathway at the VBI70 site is accidental ingestion (that is, swallowing) of contaminated soil and household dust by both children and adults. This exposure occurs when people have direct contact with soils in their environment. For instance, when children play outside or crawl on floors or when adults work in yards and gardens, contaminated soil or dust particles cling to their hands. Residents can then accidentally swallow the contaminants when they put their hands on or into their mouths, as children often do. Since both people and pets track contaminated soils from outdoors into their homes, exposures can occur while people are in their homes and while they are in their yards. Factors that affect whether or not people have contact with contaminated soil include:

- grass cover, which is likely to reduce contact with contaminated soil when grass cover is thick but increase contact with soil when grass cover is sparse or bare ground is present,
- weather conditions, which is likely to reduce contact with outside soil during cold months because people tend to stay indoors more often,
- the amount of time someone spends outside playing or gardening, and
- people's personal habits when outside, for instance, children whose play activities involve playing in the dirt are likely to have greater exposure than other children.

Unless contaminants are removed from properties, some residents will be exposed to contaminated soils and dust as long as they live in the VBI70 study area. The contaminants of concern for soil ingestion at the VBI70 site are arsenic and lead.

The amount of chemicals that people are exposed to via ingestion depends on many factors, such as the levels of contamination at their homes and the type of activities while at home. The highest amount of exposure to levels of soil contamination is expected to occur among people who spend time at their homes. The people who live at these homes will have the most exposure, and neighbors who are visiting these homes can be exposed to a lesser degree. For reasons described below, preschool children, whether they live at homes with contaminated soils or who frequently visit homes with contaminated soil, have the highest potential for exposure. On the other hand, adults and older children who visit houses with contaminated yards probably have much less exposure because they put their hands on or into their mouths less frequently than preschool children.

Another factor that greatly affects people's exposure is the amount of soils they accidentally ingest on a daily basis. Though people might not be aware of this, everyone ingests some soil or dust every day, but some people tend to swallow more soil or dust than others. Preschool children, on average, swallow more soil and dust than people in any other age group. This is because some preschoolers often have close contact with soil and dust when they play and because they tend to engage frequently in hand-to-mouth activity. Children in elementary school, teenagers, and adults are also exposed to dusts and soils, but generally in much smaller amounts.

Soil-pica

When evaluating exposures, ATSDR also considered a wide range of human activities that might increase exposure to arsenic and lead in soil. One activity that may increase concern, particularly in preschool children, is a behavior called "soil-pica", the eating or ingestion of large amounts of soil. This behavior occurs in some preschool children as part of their normal exploratory behavior for 1- and 2-year old children, as part of an intentional behavior in older preschool children (3 to 6 year olds), or accidentally as they eat food dropped on the ground that picks up soil particles. The reasons why some children engage in soil-pica behavior is not known. Scientists suspect that soil-pica behavior has something to do with nutritional deficiencies, psychological needs, and cultural factors (Danford 1982), but none of these links have been proven or shown to be responsible for all soil-pica behavior. Soil-pica behavior is most likely to occur in preschool children, but it can occur in older children and even in adults. The exact number of children who go through a stage of pica behavior is not known. Studies have reported that this behavior occurs in as few as 4% of children or in as many as 21% of children (Barltrop 1966, Robischon 1971, Shellshear 1975, Vermeer and Frate 1979).[11] Using statistics, two scientists have estimated as many as 33% of preschool children will have soil-pica behavior once or twice during their preschool years (Calabrese and Stanek 1998). They admit, however, that their 33 percent may overestimate the percentage of children who engage in 1 to 2 days of soil-pica behavior (Calabrese and Stanek 1993, Danford 1982, EPA 1997). The percentage of children in the VBI70 study area with soil-pica behavior is unknown.

Studies on children have shown that soil-pica children eat varying amounts of soil ranging from 600 mg to 5,000 or more milligrams (about 1/8 teaspoon to 1 teaspoon) (Stanek and Calabrese 2000, Calabrese and Stanek 1993, Calabrese et al. 1989, Wong 1988). Because of the limited number of such studies, some uncertainty exists in deciding what amount of soil intake should be

[11] This means that as few as 4 or as many as 21 out of every 100 children might have soil-pica behavior.

used for soil-pica children. Therefore, for this public health assessment, ATSDR will use a range of soil intakes from 600 to 5,000 milligrams soil to estimate exposure for soil-pica children.

Limited information is also available for how often (i.e., frequency) and how long (i.e., duration) soil-pica children will have this behavior. Some preschool children might eat soil once during their preschool year while others might go through a stage of eating soil several times during a week or over several months. It is reasonable to assume that soil-pica behavior might occur for several days in a row, or a child might skip days between eating soil (Calabrese and Stanek 1998; Calabrese and Stanek 1993; Wong 1989, ATSDR 1992.) In addition, general pica behavior is greatest in 1- and 2-year old children and decreases as children age during their preschool years (Barltrop 1966).

Since the Denver climate is relatively dry, especially in the summer, many homes have yards with exposed soil and little grass cover. Some children with soil-pica behavior who live in arsenic-contaminated properties could easily have direct access to contaminated soils because of bare spots in the yard. Moreover, since winters in Denver are generally cold, soil-pica behavior is less likely to occur during this time and probably most likely to occur during the warmer summer months, when preschool children are most likely to play outside. No studies have been conducted to determine the percentage of children in the VBI70 study area that have soil-pica behavior. As part of future activities, ATSDR is considering developing a questionnaire that would identify soil-pica behavior in children.

Studies have also shown that adults will engage in soil-pica behavior, which is often referred to as geophagy, the eating of earth. Geophagy in adults results largely as a cultural practice in the US and usually involves eating clay. Quite often pregnant women will eat clay because they believe it is beneficial. Another practice that is becoming more common in the US is the commercial marketing of bentonite clays to people who believe it cleanses the gastrointestinal tract. Geophagy has been shown to occur in African-Americans, Whites, and Hispanics. For instance, a study was conducted of culturally transmitted clay eating in African-American children and adults who lived in Holmes County, Mississippi. In this case, families used designated areas to dig clay and processed the clay using heat before eating it. What is of note in this practice is that culturally instilled geophagia involves eating processed clay that is taken from below the surface and is usually not from the person's yard. (Vermeer and Frate 1979, Reid 1992, Grigsby et al. 1999, ATSDR 2001).

In addition to people with soil-pica behavior, some workers in the VBI70 study area might accidentally come into contact with contaminated soils. As an example, contractors and utility workers might work on job sites with contaminated soils. If these workers were to get arsenic-contaminated soils on their hands, and then engage in hand-to-mouth activity, they too could be exposed to the contaminants in the area.

During our work with community members, ATSDR was told about incidents of both children and adults eating soil. In one case, a community representative reported to ATSDR that a young woman who lived in the VBI70 study area ate soil from her yard. When questioned about why she ate soil, the woman reported that she did so periodically because she liked it. In another incident, a city official reported to ATSDR that a grandmother made mud pies from yard soil and fed them to her grandchildren. These incidents were described as culturally appropriate among some groups in the area. Although they cannot be used to determine the percentage of people in the VBI70 area that practice soil-pica, they are important clues that this behavior might be present.

Soil-pica workshop

As part of the Agency's efforts to reduce the hazard of soil-pica behavior, ATSDR invited national experts to a soil-pica workshop on June 7 and 8, 2000. The purpose of the workshop was to seek advice about soil-pica behavior to help ATSDR in making public health decisions. The panelist reached the following key findings during the workshop:

- The panelists agreed that soil-pica does exist.
- The panelists agreed that the percentage of soil-pica behavior at given soil intake rates is poorly defined.
- The panelists agreed that more research is needed to understand the percentage of children with soil-pica behavior and the amount of soil that soil-pica children ingest.
- The panelists agreed that while very few studies are available, ATSDR should continue to use 5,000 mg as an estimate of soil intake for soil-pica children.
- The panelists agreed that ATSDR should continue to evaluate the public health significance of soil-pica behavior.

ATSDR considered the advice of the expert panel in evaluating the potential for soil-pica behavior at the VBI70 site. The advice and recommendations of the panelists are reported in Summary Report for the ATSDR Soil-pica Workshop (ATSDR 2001).

Eating home-grown produce

Eating fruits, vegetables, herbs, or other produce grown locally in gardens with contaminated soil can cause exposure. This type of exposure occurs because many plants slowly absorb small amounts of the chemicals that are found in soils or because contaminated soil can adhere to the exterior surface of produce. Some of these absorbed chemicals are essential nutrients and are actually good for humans to eat, but other chemicals can present health hazards if they are found at high enough levels and are consumed on a regular basis. ATSDR and CDPHE evaluated the potential exposure from eating home-grown produce.

When reviewing this exposure pathway, ATSDR focused the evaluation on levels of arsenic in produce. The other contaminants in the VBI70 soils are either far less likely to be absorbed by plants (e.g., lead) or are much less toxic than arsenic (e.g., zinc). Using a method developed by EPA (EPA 1995b) and advice from the U.S. Department of Agriculture, ATSDR and CDPHE estimated the amount of arsenic that residents in the VBI70 study area would ingest if 30% of the produce that they ate came from their home garden. However, this analysis found that the amount of arsenic that people might ingest by eating home-grown produce is far below the amounts that are known to cause harmful effects.

Residents in the VBI70 study area have recently received two important fact sheets with public health information about eating home-grown produce. In April 1999, while ATSDR and the Colorado Department of Public Health and Environment (CDPHE) were evaluating specific health risks for the VBI70 site, CDPHE published and released the first fact sheet, which described how garden produce can absorb soil contaminants and explained how residents can protect themselves from these contaminants. A copy of this fact sheet is presented in Appendix E. In August 1999, after the public health agencies finished evaluating the risks of eating home grown produce, ATSDR published and released a fact sheet which informed residents that it was safe to eat fruits and vegetables from their home gardens, because the amount of arsenic that these plants absorb is likely far below levels that might harm the people who eat their produce.

Possible (Potential) Exposure Pathways

When important information about an exposure pathway is missing or incomplete, ATSDR classifies it as a possible (or potential) exposure pathway. In these cases, not enough information is available to conduct detailed analyses of the amount of exposures to contaminants in areas where people live, work, and play. ATSDR has identified three potential exposure pathways for the VBI70 site. The following discussion identifies these pathways and the missing information.

Ingesting or Touching Sediment and Surface Water

Rain water and snow melt can carry contaminants from the air and surface soil into local "surface waters," such as drainage ditches, creeks, streams, and rivers; some of the contaminants can then settle into the sediments at the bottom of these locations. People who play or work in these areas, in turn, can accidentally come into contact, or even swallow, small amounts of the contaminants in the water and sediments. Recognizing this route of exposure, ATSDR gathered and reviewed information on contamination in sediments and surface waters in the VBI70 study area, as described below.

Sediments

ATSDR identified only one study that measured levels of contamination in the sediments of local surface waters.[12] This study was conducted in 1997 by CDPHE and focused on the sediments and surface water of the South Platte River—the main water way that flows through the VBI70 study area. During this study, three sediment samples were collected: one from where the river

[12] ATSDR is investigating whether or not studies of the South Platte River have been conducted as part of CDPHE's investigation of the nearby Globe ASARCO Plant Site.

flows beneath I-70 (near the Denver Coliseum), one approximately one-half mile upstream from this location, and one approximately one-half mile downstream from this location (Apostolopoulos 1998). The samples were analyzed for concentrations of metals, including arsenic, lead, and cadmium. While these metals were detected in sediment, none were found at unusually high levels.

ATSDR cannot be certain that contamination in the sediments in the VBI70 study area has not reached potentially unhealthy levels for two reasons. First, the limited sampling during the 1997 study does not provide an extensive account of contamination in the South Platte River. The three samples might have been collected in areas with relatively "clean" or relatively "dirty" sediments. The study's findings would not reflect levels of contamination in the sediments throughout the South Platte River. Second, ATSDR could not find sampling results for the sediments in the other surface-water bodies in the VBI70 study area, such as creeks and drainage ditches. Without more sampling data, it is impossible to determine whether contaminated sediments might harm children or adults. ATSDR notes, however, that contaminated sediment would pose a health hazard only if people, and particularly children, routinely contacted the sediments, which does not seem likely in the VBI70 study area.

Surface Water

ATSDR has identified only one study—CDPHE's 1997 study, which was described above—that measured levels of contamination in the surface waters in the VBI70 study area.[13] During this study, CDPHE collected three surface-water samples from the South Platte River, in the same locations where sediment were sampled (see previous subsection).

Although some contaminants have been detected in the South Platte River, the residents in the VBI70 study area rarely, if ever, come into contact with them. For exposure to occur, people would have to swim or wade in the South Platte River—an activity that presumably occurs only during the warmer summer months, if at all. Since arsenic and lead, the contaminants of concern at this site, do not readily pass through skin, wading in the river will likely not result in any exposure to these chemicals. To be exposed to the chemicals in the water, residents would have to swallow river water accidentally, but the likelihood of this happening is extremely low. Therefore, significant exposure to the contaminants that were detected in the South Platte River seems unlikely.

If residents come into contact with surface water in drainage ditches, streams, and puddles in the VBI70 study area, simply coming into contact with these surface waters would not result in exposure, unless the residents actually drank from these waters, which seems highly unlikely. It is unlikely that surface water could be a significant route of exposure for people who live in the VBI70 study area.

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[13] ATSDR is also investigating whether or not studies of the South Platte River have been conducted as part of CDPHE's investigation of the nearby Globe ASARCO Plant Site.

Drinking groundwater

The groundwater beneath the VBI70 study area has not been tested. EPA has stated that it plans to investigate potential groundwater contamination in this area at a later date. Until then, however, levels of contamination in the groundwater are not known, preventing ATSDR from fully evaluating the public health significance of potential groundwater contamination. ATSDR notes, however, drinking water at all residences in the VBI70 study area is drawn from surface waters from the nearby Rocky Mountains. Therefore, even if the groundwater beneath the VBI70 study area were contaminated, it is highly unlikely that residents would ever drink the contaminated groundwater. Nonetheless, ATSDR will evaluate the public health significance of groundwater contamination, if evidence of contamination becomes available.

Breathing outdoor and indoor air

The contaminated soils and dusts in the VBI70 study area can become airborne by various processes. For example, high winds can blow fine soil and dust particles into the air, as can cars driving on roadways covered in small amounts of dust and dirt. Because the Denver area has a relatively dry climate and heavy traffic, dusts and surface soils can become airborne more easily in the VBI70 study area than in other parts of the country. These airborne contaminants can enter homes through open doors, open windows, and air intake vents. Unfortunately, ATSDR cannot evaluate the amount of contaminants in the outdoor or indoor air in the VBI70 study area, because the appropriate air monitoring data measuring arsenic and lead in air are not available for this part of Denver.

If homes exist atop contaminated soils, the contaminants can slowly accumulate in the air in the crawlspace beneath a house if the soil is disturbed, and they can enter homes through air intake vents, if the intake vents are located in the crawlspaces. In these cases, people inside their homes might be exposed to small amounts of contaminated dusts that come from their crawlspaces. In general, this type of exposure occurs for contaminants that readily evaporate (such as gasoline), and occurs to a much lesser extent, if at all, for those that do not readily evaporate (such as arsenic and lead, the main contaminants of concern for this site). Because no sampling studies have measured levels of contamination in either crawlspace air or indoor air, ATSDR cannot determine whether this type of exposure is actually occurring in the VBI70 study area.

As previously noted, no agency has collected indoor or outdoor air samples in the VBI70 study area that characterizes air quality throughout the site. After the EPA finishes investigating levels of contamination in soils, they will decide whether a follow-up investigation of air pollution in the study area is necessary. ATSDR will review data generated by such studies, if they are conducted.

Arsenic and Lead Patterns in the VBI70 Study Area

As previously discussed, ATSDR has found that soil contaminated with arsenic and lead present the greatest public health hazard at the VBI70 site. Focusing on the contaminated soils, ATSDR has evaluated how levels of lead and arsenic vary from one location to the next in the study area. This evaluation was necessary to determine whether the previous EPA soil sampling studies were sufficient and whether the studies should be expanded to consider soil contamination in other nearby areas. The following discussion reviews ATSDR's findings about levels of soil contamination throughout the VBI70 study area.

Lead distribution throughout the study area

The Phase III sampling data, which includes results for 2,986 properties, provides an excellent account of how levels of lead in surface soils vary throughout the VBI70 study area. As an example, Figure 10 in Appendix B illustrates the sampling results by showing the locations with the higher lead concentrations which are symbolized by the darker circles and the locations with the lower lead concentrations are the lighter circles. The higher levels of lead in soils (or the darker circles) occur more frequently in the Elyria and Cole neighborhoods and the lower levels of lead in soils (or the lighter circles) occur more frequently in the Swansea and Clayton neighborhoods. In other words, the levels of lead in surface soils appear to increase as one travels west in the VBI70 study area.

Figure 11 in Appendix B presents a similar account of the Phase III sampling results, by looking at the distribution of lead levels below and above 400 ppm. As Figure 11 shows, the same data trend is apparent—higher levels of lead in the western portion of the study area than those in the eastern portion. The same pattern appeared when the ranges were set at 101 to 190 ppm and 191 to 282 ppm. Therefore, the somewhat arbitrary choice of concentration ranges in the figures appears to have no bearing on the data trend. The same trend is also seen when plotting Phases1 and II data.

One possible explanation for this trend is that fallout from one of several nearby smelters has raised lead levels in surface soil. Other possible explanations also exist. For instance, the western portion of the site is closer to the intersection of Interstate 70 and Interstate 25 and so fallout from leaded gasoline might have increased lead levels in nearby yards. Another possible explanation is that the homes in the western portion of the site are older and therefore more likely to have lead paint on the exterior. The implication is that years of weathering and chipping paint have contaminated the yards. This explanation seems unlikely since the percentage of older homes (for instance, homes built before 1950 when high amounts of lead were commonly added to paints) is very similar in Elyria and Cole compared to Swansea and Clayton (see Appendix D, Table D-1). ATSDR identified other data trends that deserve mention:

- The five highest soil concentrations of lead observed in the VBI70 study area during the Phase I and II sampling occurred at three properties located within 1,000 feet of the former Omaha-Grant smelter. Four of the five highest levels came from samples taken below the surface (see Appendix B, Figure 12). This trend indicates that significant lead contamination in subsurface soils might occur near the former smelter.

- Surface-soil sampling data from the Globeville community showed a distinctive north-south trend in soil-lead concentrations, in addition to the east-west trend discussed above for the VBI70 study area. As Figure 13 in Appendix B shows, relatively lower lead levels were found in the northern portions of Globeville, while relatively higher lead levels were found in the southern areas.

- An interesting observation is that the variations in zinc concentrations in surface soils (see Figure 14 in Appendix B) throughout the study area are quite similar to the variations in lead concentrations (see Figures 10 and 11 in Appendix B).

- The maps show that the industrial area near the center of the VBI70 study area has not been extensively sampled. Therefore, levels of contamination in this area remain unknown.

In review, the trends depicted in Figures 10, 11, and 13 indicate that significant soil-lead contamination is likely to exist south and west of the VBI70 study area. In other words, significant lead contamination might exist south of Martin Luther King Boulevard/Blake Street and west of Fox Street/Burlington Northern Railroad, though these soils have not been tested by EPA's sampling efforts. In addition, significant soil lead contamination may exist in the industrial area in the center of the VBI70 study area.

Lead distribution at individual properties

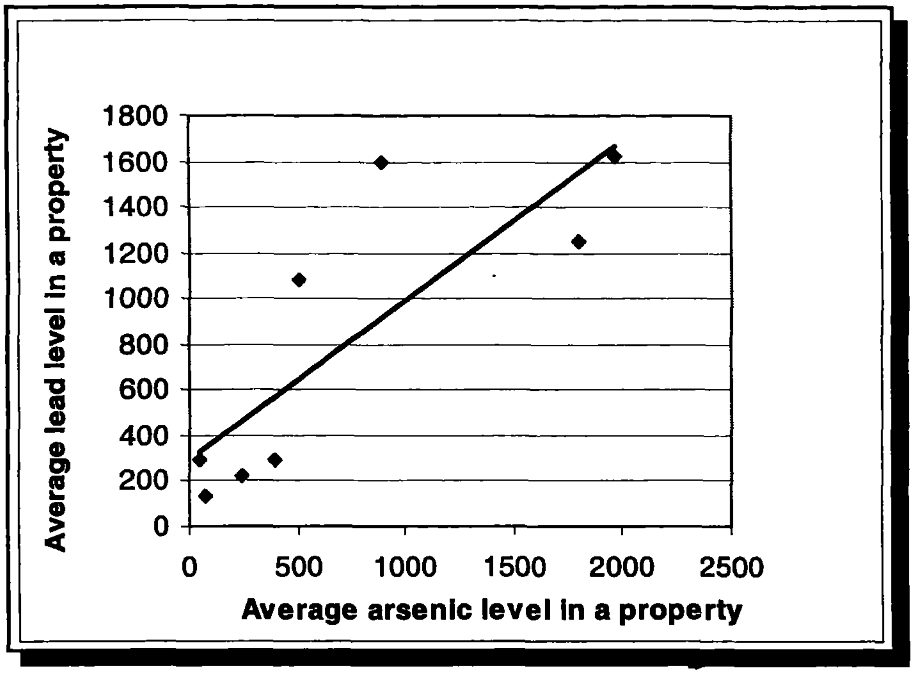
Because of EPA's intensive sampling effort at eight properties in the study area, it is possible to evaluate lead distribution patterns at those properties and in some of the adjoining yards that EPA also sampled. The properties with high levels of lead generally show consistently elevated lead levels throughout the yards while lead levels in adjoining properties drop off significantly. There appears to be, however, some migration of lead onto adjoining properties (see Appendix B, Figure 15.) This pattern of high lead levels dropping off at the property boundary is similar to the pattern for properties with high arsenic levels and may point to a similar mechanism by which lead got into the soil at properties that are highly contaminated.

A comparison of lead and arsenic levels in soil for the eight intensively sampled properties showed that as lead levels go up, arsenic levels tend to go up also. This correlation is shown in Graph 2 that follows, but it is not apparent when looking at Phase III data. ATSDR is unsure of the significance of this finding and wants to point it out as information for the other agencies to investigate.

Arsenic distribution in the study area

As part of ATSDR's normal evaluation process, the agency also evaluated how soil arsenic concentrations vary from location to location in the VBI70 study area. When looking at a plot of Phase III data, no obvious patterns in arsenic concentrations were apparent when looking at high arsenic levels (see Figure 16 in Appendix B). The high arsenic levels appeared to be scattered randomly around the study area. However, a pattern exists for low levels of arsenic.

Graph 2



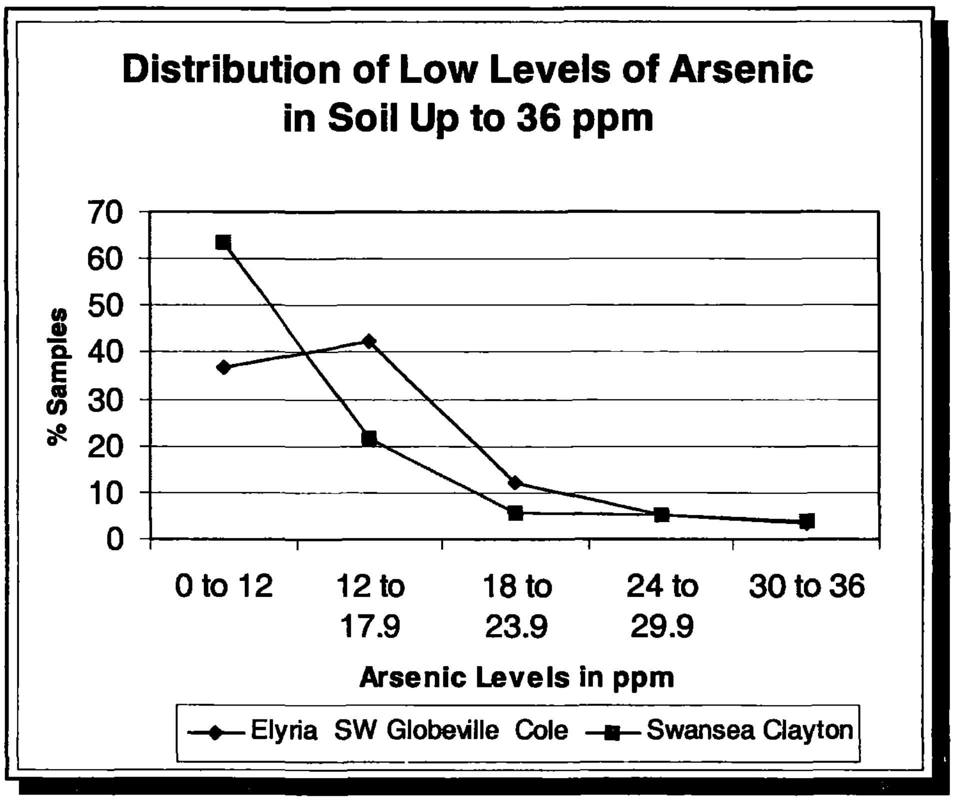
Comparison of average arsenic levels to average lead levels
for the eight intensively sampled properties

Figure 17, Appendix B shows the distribution of arsenic levels for 0-11 ppm and 12 to 29 ppm, which is similar to the lead pattern described previously. That is, at these lower levels of arsenic, samples in the range of 12 to 29 ppm are found more frequently in the western portion of the study area, that is Cole, Elyria, and Southwest Globeville. Figure 18, Appendix B shows a similar pattern when looking at the ranges of 12 to 17 ppm and 18 to 23 ppm. These levels of arsenic in soil are unlikely to cause harmful effects in people at the VBI70 site. ATSDR points out this distribution pattern because it might point to another source of arsenic in the neighborhoods in addition to arsenic-based pesticides.

The number of samples collected from a neighborhood might visually influence what is seen when plotting the data in Figures 17 and 18. To address this potential problem, ATSDR determined the sampling density for Phase III (see Appendix B, Figure 19.) Figure 19 shows some minor differences in the number of soil samples collected from each neighborhood. For instance, it appears that based on sampling density, fewer samples were collected from Clayton. To ensure the pattern in Figures 17 and 18 was not being influenced by the difference in the number of samples from each neighborhood, ATSDR calculated the percentage of low-level arsenic samples in various ranges for each neighborhood. If no pattern exists, the percentages should be similar in each neighborhood. As Table 4 shows, the percentage of samples is different when comparing Elyria, Southwest Globeville, and Cole to Swansea and Clayton.

As can be seen in Graph 3 that follows, this difference is apparent when comparing the distribution of low arsenic levels in Elyria, Southwest Globeville, and Cole to the same distribution of low arsenic levels in Swansea and Clayton. To determine if the distribution of low arsenic levels in Elyria, Southwest Globeville and Cole is different from the distribution of low arsenic levels in Clayton and Swansea, ATSDR compared the distributions mathematically.

Graph 3



The results showed that the pattern of arsenic percentages between Elyria, Southwest Globeville, and Cole is statistically different from the pattern of arsenic percentages in Clayton and Swansea.[14] It seems reasonable to assume that this pattern may be the result of fallout from the nearby smelters.

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[14] Using the Chi-square test, the p value was < 0.0001. This p value indicates that the difference between the two distributions is most likely real.

Table 4. Percentage of samples in various ranges of arsenic levels					
Neighborhood	% less than 12 ppm	% 12 to 17.9 ppm	% 18 to 23.9 ppm	% 24 to 29.9 ppm	% 30 to 36 ppm
Elyria	28	46	17	8	0.6
SW Globeville	31	42	17	8	2
Cole	40	42	10	4	4
Clayton	64	21	6	5	4
Swansea	63	22	5	5	5

In addition to these observations about low levels of arsenic, another important observation can be made about high levels of arsenic in soil. Since Phase III sampling detected relatively high levels of arsenic at residences very close to the boundary of the VBI70 study area, elevated arsenic concentrations might occur in areas beyond the current VBI70 study area. This conclusion is supported by a report released with EPA's assistance by the National Association of Black Environmentalists (NABE.) Collecting soil samples from 36 properties in the Northeast Park Hill neighborhood in March and August 1999, NABE found many yards with elevated levels of arsenic in soil. The highest arsenic level detected was 1,010 ppm. In addition, according to a staff member with the CDPHE, Dr. Drexler, a professor with the University of Colorado, has found high levels of arsenic in yards from other parts of Denver.

It is important to evaluate the population density in the area surrounding the VBI70 study area when making decisions about the significance of possible contamination outside the VBI70 study area. Figure 20 in Appendix B shows the population density for the neighborhoods surrounding the VBI70 study area. Using this map and previous figures showing patterns of arsenic contamination, there are areas outside the VBI70 site with unknown, but possibly significant, arsenic contamination in soils . They include:

- Residential neighborhoods south, west, and north of the study area, south of Martin Luther King Boulevard/Blake Street, west of Fox Street/Burlington Northern Railroad, and north of southwest Globeville.
- Residential neighborhoods east and southeast of Clayton,
- The industrial area in the central portion of the VBI70 study area, and
- Other possibly other residential neighborhood in the Denver area.

Arsenic at individual properties in the study area

Because of EPA's intensive sampling effort at eight properties, it is possible to understand the distribution of arsenic levels in soil at those properties, which helps in evaluating people's exposure to arsenic. Arsenic distribution in highly contaminated properties can be consistently high throughout the property, (see Figures 21 and 22, Appendix B) or it can be found at high levels in isolated spots throughout the property (see Figure 23, Appendix B). This pattern of patches of high arsenic contamination is important to understand when evaluating children's exposure to arsenic since children can play in any part of the yard.

EPA collected many soil samples from adjoining properties for six of the eight intensively sampled properties. At five of those six properties, elevated arsenic levels in soil were found at the property line of the adjoining yard, although the arsenic levels in soil from the adjoining properties were lower than those from the original properties. The arsenic might have migrated onto the adjoining property as part of surface-water runoff. In some cases, past landscaping or construction activity may have also caused the movement.

Discussion of the Public Health Significance of Contaminants

Possible Health Effects from Exposures to Arsenic

Background: Human studies about the health effects of arsenic

ATSDR reviewed the findings from numerous studies that have documented the effects of arsenic on humans. Most of these studies examined what happens to people who drink water contaminated with arsenic. Though drinking contaminated water does not appear to be an important exposure pathway at VBI70, the results of these studies are relevant for evaluating effects of accidentally or purposely ingesting soils contaminated with arsenic. Findings from three of the studies on arsenic toxicity are presented here:

- In Taiwan, a community of 40,000 people unknowingly used groundwater contaminated with arsenic as a drinking supply for roughly 45 years. People of all ages experienced effects on the skin (specifically small blotches of increased skin pigmentation or hyperpigmentation and a skin condition known as keratosis), skin cancer, and several types of internal cancer.[15] The concentration of arsenic in well water ranged from 50 ppb to over 1,000 ppb with a typical value of about 500 ppb. ATSDR derived an estimate of the lowest dose (intake) that is most likely to result in an adverse (noncancerous) effect (or LOAEL). This LOAEL was 14 micrograms arsenic per kilogram body weight per day or a daily intake of about 800 micrograms of arsenic per day.

  The most common outward effects of arsenic exposure are hyperpigmentation and keratosis. Appendix G contains photographs of hyperpigmentation on someone's arm and keratosis on someone's hands and heals. The keratosis in Appendix G is a severe case of keratosis. The youngest person to experience increased skin pigmentation in the Taiwan study was 3 years old; the youngest person to experience keratosis was 4 years old; and the youngest person to experience skin cancer was 24 years old. Appendix G also has a photograph of arsenical-induced skin cancer. The number of people who experienced health effects increased with each decade of exposure to arsenic in drinking water with the highest number of cases occurring when people were 60 to 70 years old. This study showed that while young children can experience harmful effects from arsenic, generally long-term exposure for many decades are required before many cases will appear in a community (ATSDR 2000.)

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15 Arsenic-induced hyperkeratosis is a skin condition found most often on the feet and palms. Many small depressions occur in the skin with small, hard, outgrowths of skin in the center of each depression. Hyperkeratosis can also appear as scaling skin. Hyperpigmentation of the skin occurs as small brown areas or blotches on the skin around the eyelids, temples, neck, nipples, and groin. In severe cases, pigmentation may cover the chest, back, and stomach. It sometimes appears as mottling on the skin and has been described as looking like raindrops. If mottling occurs, it is more frequent on the chest, back, and stomach.

- In West Bengal, India, and neighboring Bangladesh, a large population unknowingly used arsenic-contaminated groundwater since the late 1960s. In West Bengal, about 800,000 people are thought to be using contaminated wells. Harmful effects detected in this population include weakness, skin changes (hyperpigmentation and keratosis), enlarged livers, breathing effects, and cancers. Health effects involving changes in the skin have also been documented in children and teenagers as well as adults (Mazumder et al. 1998, ATSDR 2000.)

  Many studies exist for arsenic exposure in India and Bangladesh and so a wide range of arsenic levels in water have been found. In one such study, arsenic levels ranged from less than 50 ppb to over 800 ppb with the highest level detected being 3,400 ppb. Over 80% of the population, however, used drinking water with arsenic levels below 500 ppb. In this study of 7,683 people, the authors found 12 cases of keratosis and 27 cases of hyperpigmentation in people drinking water containing between 50 and 100 ppb arsenic. Using an average of 75 ppb and a range of water intakes (2 liters per day to 4 liters per day), the estimated daily intake of arsenic for this group ranges from 150 to 300 micrograms arsenic per day (Mazumder 1998). The authors, however, stress that some uncertainty exists in classifying people as to their arsenic intake.

- In Chile, another community, again including children, drank water from a supply that was contaminated with arsenic. Some children in this community had health effects similar to the children in West Bengal, and others had additional skin problems, such as areas of scaly skin with decreased pigmentation (ATSDR 2000.) As with the other populations studied, harmful effects were found in all age groups.

  Arsenic levels in drinking water for this population ranged from 600 to 800 ppb and people were exposed for a maximum of 12 years. Estimated daily arsenic intake for these children is probably around 600 to 1,600 micrograms per day depending on how much water they drank. After 4 years of exposure, children were found with a variety of health effects.

- In 1962, the dust collecting system for a smelter operation in Utah failed resulting in large amounts of arsenic trioxide and sulfur dioxide being emitted into the air. Fallout from these emissions contaminated a nearby community of 250 residents. Thirty-two of 40 children examined in this community showed signs of adverse effects on the skin. These skin effects are different from the skin effects (hyperpigmentation and keratosis) that are caused by long-term exposure to arsenic. In addition to skin effects, some children experienced redness of the eyes and nose, and sinus problems. The author also reported that most of the cats and dogs had died. After temporarily closing the mill and a change in wind direction and rain, the skin conditions improved in a few weeks (Birmingham 1965).

  Arsenic is known to cause skin irritation in the workplace causing redness and swelling after contact with arsenic dust (ATSDR 2000). One question that arises for the smelter episode is whether or not arsenic exposure alone was responsible for causing skin irritation in children or whether sulfur dioxide is needed. This prompted the authors to apply arsenic trioxide to the skin of rabbits. Skin irritation in rabbits occurred only when the authors applied arsenic trioxide between the skin folds of rabbits. Apparently, the arsenic trioxide does not cause open sores from direct skin contact but rather from the combination of moisture, arsenic trioxide, and the rubbing action that occurs in the folds of skin. It may also be the case that sulfur dioxide in the smelter episode increased the potential of arsenic trioxide to cause skin irritation.

Unfortunately, the authors did not test extensively the environment that the children played in, although grass was found to contain 925 ppm arsenic. Therefore, it is not possible to know exactly how much arsenic was in the children's play area that resulted in skin effects (Birmingham et al. 1965).

Overall, the studies have one important finding in common: high exposure to arsenic for many years has the potential to cause harmful health effects in both children and adults. ATSDR's evaluation of the VBI70 site considers the findings of the previous studies and many other studies showing the effects of arsenic on humans. ATSDR compares site-specific estimates of exposure to arsenic in VBI70 residents to exposure levels presented in the previously mentioned studies.

Uncertainty issues in deciding possible adverse health effects

Uncertainty based on estimated exposure

Much of the uncertainty involved in deciding whether or not adverse health effects might occur comes from estimating how much arsenic people are exposed to from living in properties with arsenic-contaminated soil. As mentioned previously, some children and adults are exposed to arsenic in soil from hand-to-mouth activity. This activity results in varying amounts of ingested soil each day. For children, studies lasting a couple of weeks have shown that most children ingest between 10 and 50 milligrams (mg) a day while a smaller group of children ingest up to 200 mg a day. A recent study of 64 preschool children who live in Anaconda, Montana, showed an average soil intake of 30 mg a day and a maximum soil intake of about 200 mg a day (Stanek and Calabrese 2000). Uncertainty arises in using these average and near maximum values for the following reasons:

- the studies take place over a 1 to 2 week period and scientists have to assume that the results represent soil intake throughout the year,
- the studies involve a small number of children and scientists have to assume that the results apply to all children,
- the studies involve children from a relatively small geographic area and scientists have to assume that the results apply to children from other geographic area,
- the studies take place in warm weather when children are likely to spend more time outdoors and scientists have to assume that the results represent soil intake during cold weather when children are likely to spend more time indoors,

- no studies are available for elementary school children and teenagers so scientist have to use results from studies conducted on preschool children, and
- even fewer studies have been conducted on adults.

Most public health agencies in the United States use 200 mg soil a day to estimate exposure in preschool children with high soil intake. In this evaluation, ATSDR will use this value as well as 30 mg soil a day to estimate exposure for preschool children with typical soil intake. When estimating exposure in other age groups, ATSDR will use 30 and 100 mg soil a day for elementary school children, teenagers, and adults.

At the VBI70 site, children with soil-pica behavior are a special concern to the agency because ingesting high amounts of soil could lead to significant arsenic exposure. The information that is available is reported in Discussion of Exposure Pathways Section in the subsection about soil-pica. The uncertainty that exists when evaluating soil-pica follows:

- only a few studies are available that report how much soil-pica children ingest,
- only a few studies are available that report the percentage of children with soil-pica behavior,
- very little information is available about how often soil-pica occurs during a week or during a month,
- no information is available about soil-pica habits during cold weather, and
- very little information is available about the frequency of soil-pica behavior as children age.

No studies have been conducted specifically in the VBI70 study area to gather information about the different points raised in the previous bullets. Therefore, ATSDR has to rely on the limited information from other studies about soil-pica. As previously mentioned, soil-pica children may eat as much as 5,000 milligrams (or about 1 teaspoon) of soil at a time, and that soil-pica children can eat soil one time, or three or four times during a week for several weeks.

<u>Uncertainty based on arsenic toxicity</u>

Uncertainty when deciding about possible adverse effects also exists because of how arsenic interacts with the human body. Not all the arsenic that is eaten actually gets into the body since some arsenic will pass through someone's system. For example, some arsenic is bound so tightly to soil particles that it is less likely to be absorbed by the lining of the intestinal tract (the gut) than arsenic bound loosely to soil particles. This phenomenon of how much arsenic actually crosses the gut and gets into the body is called bioavailability. For instance, if only half of the arsenic in soil is capable of getting into someone's body, the soil arsenic is referred to as being 50 percent bioavailable. The uncertainty at the VBI70 site is what percentage of arsenic in soil is bioavailable to humans when they ingest it. For the VBI70 site, ATSDR assumed an upper range of bioavailability to be between 40 and 60 percent.

In addition, if someone has eaten recently, the time it takes for arsenic to be absorbed through the gut might increase and this might change the degree to which arsenic will cause harmful effects.

Additional uncertainty comes from the studies where arsenic is usually dissolved in water or some other fluid. In such cases, chemicals dissolved in water tend to mix more readily in the contents of the intestinal tract that are near the absorption sites (Gilman et al. 1993). Since the arsenic is already dissolved in water and in close contact with the intestinal tract, it is likely to be more quickly absorbed by people compared to arsenic bound to soil. Therefore, the health effects that are reported from drinking water studies may or may not reflect the possibility of health effects in people who ingest soil containing arsenic.

Possible skin irritations

At the VBI70 site, children who play in arsenic-contaminated soil and adults who garden in arsenic-contaminated soil could easily get arsenic-bound soil on their skin, particularly in the folds of the skin around their knees and elbows. What is uncertain at this point is whether or not arsenic levels at the more highly contaminated properties (for instance, arsenic levels above 1,000 ppm) could cause the same skin effects as found in children who lived near the previously described Utah smelter and who were similarly exposed to arsenic in soil and dust. Although it is uncertain at this time because of limited scientific data, a concern exists that arsenic at the most highly contaminated properties might cause skin irritation. If skin irritation occurs from contact with arsenic in soil, possible symptoms include:

- redness, swelling, and itching of the skin particularly around the face or where skin folds occur such as with the knees and elbows, and
- redness of skin surrounding hairs mostly on the face and neck,

In addition to these skin effects, direct contact with arsenic-contaminated soil might also cause irritation of the eyes and nasal passages. Such harmful effects have been seen in occupational exposures and in one community where residents were exposed to arsenic in the environment. It seems unlikely that low levels of arsenic in soil could cause these harmful effects.

Background information on evaluating soil ingestion

As previously mentioned, children have a range of soil intakes with a daily average soil intake somewhere around 30 to 60 milligrams (mg) (about 1/16 teaspoon). For instance, a child might have a daily soil intake for a week that looks like this: 10 mg, 40 mg, 30 mg, 5 mg, 90 mg, 50 mg, and 20 mg, which averages out to be 35 mg a day. This intake probably results from daily hand-to-mouth activity. Some children have a higher daily average and studies have shown that average daily soil intake for these children is somewhere between 100 and 200 mg. For these children with typical soil intakes, some will practice soil-pica behavior. Studies have shown that the amount of soil ingested during a soil-pica episode varies and ranges from levels above 200 mg to 5,000 mg or more. For instance, a study of children living near a smelter site in Montana found one child with a soil-pica intake of 600 mg. Typical soil-pica intakes are probably around 5,000 mg (Stanek and Calabrese 2000, Calabrese and Stanek 1993, Calabrese et al. 1989, Wong 1988). To estimate exposure from soil intake, ATSDR used a range of soil ingestion rates. The range includes the following amounts of soil: 30 mg, 60 mg, 200 mg, 600, 1,000 mg, 3,000 mg, and 5,000 mg of soil.

Another factor to consider for soil-pica children is the frequency of soil-pica episodes. To incorporate frequency, ATSDR assumed a one-time soil-pica episode and a 3-day soil-pica episode over a week or for several weeks. Since it is reasonable to assume that a preschool child might play in the most contaminated part of a yard, ATSDR used the estimated maximum arsenic level in the property based on Phase III data. To estimate the maximum arsenic level, ATSDR used the average arsenic level in the yard and the regression formula described previously.

To determine if harmful effects might be possible ATSDR first compared the estimated amount of arsenic exposure (or dose) to the Agency's "health guideline" dose for acute exposures to arsenic. The health guideline dose or Minimal Risk Level is an exposure level below which you would not expect to find harmful health effects.[16] In the case of arsenic, ATSDR has developed a provisional acute oral Minimal Risk Level (MRL) for arsenic of 0.005 mg/kg/day.[17] The MRL was is based on several transient (i.e., temporary) effects and include nausea, vomiting, and diarrhea. The dose of 0.005 mg/kg/day means 0.005 milligrams of arsenic per kilogram body weight per day. When an estimated acute dose of arsenic is below 0.005 mg/kg/day, then non-cancerous harmful effects are unlikely. It is important to note several things about the MRL:

- the MRL is 10 times below the levels that are known to cause harmful effects in humans
- the MRL is based on people being exposed to arsenic dissolved in water instead of arsenic in soil, a fact that might influence how toxic arsenic is,
- the MRL applies to non-cancerous effects only and is not used to determine whether or not people could develop cancer (ATSDR 1992, ATSDR 2000).

Possible non-cancerous health effects in children with typical soil intake

Teenagers, elementary-school children, and most preschool children are not at risk of harmful effects from arsenic in soil, even at the more highly contaminated properties. (Note that the risk of cancer is discussed separately in a following subsection.) There are several reasons for this conclusion:

- their soil intake is low (ranging from 30 to 200 mg soil a day), and
- the estimated amount of arsenic exposure (or dose) is below ATSDR's provisional acute MRL of 0.005 or mg/kg/day.

Table 5 shows the estimated dose for children in different age groups with different soil intakes at the property with the highest arsenic contamination based on Phase III data. Appendix H describes how ATSDR estimated these doses.

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[16] It is important to remember that MRLs cannot be used to determine the risk of cancer.

[17] In the case of arsenic, the MRL is called provisional because the harmful effect is based on a serious health effect instead of the customary less serious health effect. ATSDR developed the provisional MRL for arsenic specifically to give health professionals guidance in evaluating acute exposures of less than 14 days.

Table 5				
Age Group	Soil Intake mg	Estimated Arsenic Dose mg/kg/day	Provisional Acute MRL mg/kg/day	Above or Below
Preschool Children 1-year old	30	0.008	0.005	Above
Preschool Children 1-year old	60	0.02	0.005	Above
Preschool Children 1-year old	200	0.05	0.005	Above
Elementary-Age Children	30	0.002	0.005	Below
Elementary-Age Children	60	0.004	0.005	Below
Teenagers	30	0.002	0.005	Below
Teenagers	60	0.003	0.005	Below
Adults	60	0.003	0.005	Below

Under certain situations the estimated amount of arsenic exposure in some preschool children might exceed ATSDR's provisional acute MRL for arsenic. Using the estimated maximum arsenic level from the property in Phase III with the highest arsenic contamination, the estimated amount of arsenic exposure for 1-year-old preschool children who ingest 30, 60, or 200 mg soil exceeds ATSDR's provisional acute MRL at some properties. Exceeding an MRL does not automatically mean that harmful effects are possible because a safety factor is incorporated into developing the MRL. In other words, the actual dose that causes harmful effects is much higher than the MRL. In this case, the estimated dose at 30 and 60 mg soil still is sufficiently below the dose that causes harmful effects. Therefore, harmful effects are unlikely. For 1-year-old preschool children who ingest 200 mg soil and who live at the most contaminated property, their estimated dose of 0.05 mg/kg/day is the same as the dose in a human study that caused temporary harmful effects.

Possible health effects that might occur include:

- nausea, stomach cramps, vomiting, and diarrhea (or frequent, loose bowel movements),
- facial swelling, particularly around the eyes, and
- headache, fatigue, chills, sore throat, and nasal discharge.

It should be noted that several conditions need to exist for these temporary harmful effects to occur. *The conditions include:*

- a one-year-old child with high soil intake approaching 200 mg day, and
- a one-year-old child who plays in and ingests soil from parts of the yard with the highest arsenic levels in soil.

In reviewing Phase III data, only one property, which has an average arsenic level of 759 ppm, has estimated exposure doses in preschool children who ingest 200 mg soil that are at levels that might cause harmful effects. As part of their cleanup efforts, EPA has cleaned up this property.

Appendix H describes the quantitative methods ATSDR used to estimate arsenic doses in children with typical soil intake.

Possible non-cancerous health effects in soil-pica children

<u>One-time exposure</u>

As mentioned previously, soil-pica children have varying amounts of soil intake ranging up to 5,000 mg or more. Table 6 shows the estimated doses in soil-pica children with varying amounts of soil intake for the property with the highest arsenic contamination in Phase III sampling data. The average arsenic level at this property is 759 ppm with an estimated maximum arsenic level of 4,856 ppm. Appendix H shows how ATSDR estimated doses to soil-pica children.

For this property, the estimated doses should a soil-pica episode occur at the most contaminated part of yard significantly exceeds ATSDR's provisional acute MRL for arsenic and is well above the level of 0.05 mg/kg/day that is known to cause temporary effects in humans.

If soil-pica children ingest large amounts of soil from the most contaminated part of a yard, about 650 of the 2,986 properties sampled so far in the VBI70 study area could be a concern for soil-pica children. Based on EPA's baseline risk assessment, EPA has identified properties as a concern for children with soil-pica behavior if the property has an average arsenic level in soil of 47 ppm or greater. Based on demographic information, about 300 preschool children live in these 650 households and somewhere between 12 to 60 of these children might have soil-pica behavior some time during their preschool years.

The health effects that might occur in some soil-pica children at these properties depend upon where in the yard children eat soil and how much soil children eat. It also depends on how quickly and how much arsenic is released from the soil particles and is absorbed through the gut. In this case, ATSDR used a range of 40 to 60 percent to estimate the bioavailability of arsenic. In addition, ATSDR's description of the possible health effects assumes that the harmful effects that might occur from arsenic in soil is similar to the harmful effects that might occur from arsenic in liquids (for instance, drinking water). As mentioned previously, these factors add some uncertainty and variation in estimating the dose and deciding which health effects might occur.

Table 6. Estimated doses for 1-year-old soil-pica children in comparison to ATSDR's provisional acute MRL

Soil Intake mg	Estimated Arsenic Dose mg/kg/day	Provisional Acute MRL mg/kg/day	Above or Below
600	0.2	0.005	Above
1000	0.3	0.005	Above
3000	0.8	0.005	Above
5000	1.3	0.005	Above

For properties where at least one of the composite samples exceeds 47 ppm, the most likely symptoms that soil-pica children might experience from a one-time soil-pica episode include:

- nausea, stomach cramps, vomiting, and diarrhea (or frequent, loose bowel movements),
- facial swelling, particularly around the eyes, and
- headache, fatigue, chills, sore throat, and nasal discharge (Mizuta 1956, Armstrong 1984, Franzblau and Lilis 1989, ATSDR 2000).

If these health effects occur, they will likely disappear within a few days provided that soil-pica behavior in contaminated parts of the yard stops.

It is important to note that about one thousand residential properties have not been sampled in the VBI70 study area and that some of these properties will have dangerous levels of arsenic in soil. About 200 of these one thousand properties might have arsenic levels that are a concern for soil-pica children.

Weekly exposure

To evaluate arsenic exposure that occurs more than one time, it is necessary to average the arsenic dose over the period of exposure. Instead of using the previously described dose of 0.05 mg/kg/day as an indicator of possible health effects, other studies sometimes become more important in deciding the possibility of harmful effects. This situation exists for arsenic when exposures occur for a week. In this case, a study reported by Armstrong et al. showed that people exposed to arsenic for a week at 2 mg/kg/day resulted in very serious health effects. Since soil-pica behavior can be habitual and occur several times in a week, ATSDR estimated arsenic doses to habitual soil-pica children.

The dose to a soil-pica for a weekly exposure is likely to be lower than the daily dose. The reason for this is that soil-pica behavior is less likely to occur every day throughout the week. It is more reasonable to assume that some children could exhibit soil-pica behavior three or four times a week. Since soil-pica behavior is likely to be less frequent when looking at a week of exposure, the dose should be averaged over the week. For those children who live in homes with highly contaminated yards, and who ingest soil from the highest contaminated area in the yard three or four times in a week, the estimated dose in these children might produce serious health effects. For instance, the estimated weekly exposure dose for a 1-year old soil-pica child who lives at the property with the highest average arsenic level is estimated to range up to 0.6 mg/kg/day depending on how much soil the child ingests. This dose is dangerously close to the dose level of 2 mg/kg/day shown in a report by Armstrong et al. that produced serious health effects (Armstrong et al. 1984, ATSDR 2000.) Some factors about arsenic toxicity, however, add some uncertainty to this conclusion. First, arsenic toxicity may be less if soil-pica behavior occurs every other day rather than several days in a row, because exposure every other day may allow the body time to recuperate. In addition, eating large amounts of soil or having food in the stomach may reduce how much and how fast arsenic is absorbed across the gut, which might reduce its harmful effects.

Based on ATSDR's estimate of arsenic exposure over a week, around 45 of the properties sampled so far in the VBI70 study area have average arsenic levels in soil that might produce serious effects in habitual soil-pica children. ATSDR considers average arsenic levels greater than about 270 ppm to be a concern for habitual soil-pica children. Since EPA has cleaned up these 45 properties, they are no longer a risk to the preschool children who live there.

As pointed out previously, however, about a thousand residential properties have not been sampled in the VBI70 study area and some of these properties will have dangerous levels of arsenic in soil. About 30 of these 1,000 unsampled properties might have arsenic levels that could produce very serious effects in habitual soil-pica children.

It is extremely important that residents and health professionals interpret ATSDR's findings in the proper context. Although there is a potential for adverse health effects to occur among some soil-pica children who are exposed to contaminated soils in the VBI70 study area, members of the VBI70 community and health professionals should note the following.

- For various reasons, not every soil-pica child who lives at or visits highly-contaminated properties will necessarily experience health effects. They may not exhibit soil-pica behavior or their soil-pica behavior might take place in a part of the yard that is not contaminated. They may also have soil-pica behavior in a highly contaminated part of the yard one day and in another part of the yard that is not contaminated or less contaminated later during the week.

- Many of the symptoms listed previously (nausea, diarrhea, vomiting) are common in children, and the symptoms have numerous causes. Therefore, if children in the VBI70 study area experience these common symptoms, it does not necessarily mean that the symptoms were caused by exposure to arsenic.

- No children have been diagnosed with arsenic poisoning in the VBI70 area that can be related to arsenic in soil; however, it is possible that cases could have been missed because the most likely symptoms (nausea, vomiting, etc.) are common symptoms in children that can result from a variety of causes.

Possible non-cancerous health effects in adults

Soil exposure for adults differs from soil exposure for children because adults have the potential for being exposed to low levels of arsenic over a much longer time frame and adults ingest smaller amounts of soil. ATSDR compared the estimated amount of arsenic exposure (or dose) to a "health guideline" dose developed specifically for many years of exposure. The health guideline dose is an exposure level below which you would not expect to find harmful non-cancer health effects. For long-term ingestion exposures to arsenic, both ATSDR and EPA use the same health guideline value. ATSDR calls its value a chronic Minimal Risk Level (MRL), and EPA calls its value a chronic Reference Dose (RfD). The chronic MRL and chronic RfD for arsenic is 0.0003 mg arsenic per kilogram body weight per day or 0.0003 mg/kg/day. It means that if people are exposed to less than 0.0003 mg/kg/day for many years, then non-cancerous harmful effects are unlikely. It is important to note that the chronic MRL and the chronic RfD apply to non-cancerous effects only and are not used to determine whether or not people could develop cancer (ATSDR 2000).

Adults ingest up to maybe 100 mg of soil each day, probably from inadvertent hand-to-mouth activity or from working in the yard. Using 30 mg or 100 mg a day for soil ingestion, the average level of arsenic in people's properties, and a bioavailability of 60 percent, ATSDR estimated the range of arsenic exposures for adults who live in the VBI70 study area. At about 45 properties with average arsenic levels above 270 ppm, the amount of arsenic exposure in adults is greater than the chronic MRL and chronic RfD for arsenic. However, the estimated arsenic exposure in adults is still well below the level where harmful health effects were observed in human studies (ATSDR 2000). Therefore, ATSDR concludes that it is unlikely that adults at any of the properties in the VBI70 study area sampled during Phase III will experience non-cancerous harmful effects from arsenic in soil.

Possible harmful effects in workers

As mentioned previously, some workers in the VBI70 study area might come into contact with contaminated soils should their work activities involved close contact with soil. For instance, contractors and utility workers might work on job sites that require digging. If these workers were to get arsenic-contaminated soils on their hands, and then engage in hand-to-mouth activity, they too could be exposed to arsenic. It is uncertain how much soil workers typically swallow but a reasonable estimate might be that workers occasionally ingest up to 500 mg. In most cases, this exposure is not likely to cause harmful effects. However, should workers ingest 500 mg or more of soil that contains high amounts of arsenic (for instance, 10,000 ppm arsenic) they might experience symptoms similar to those described for children with soil-pica behavior.[18] They might experience nausea, vomiting, diarrhea, facial edema, and headaches.

The possibility of cancer

According to EPA and the U.S. Department of Health and Human Services, arsenic is known to cause cancer in people. This judgment is based on convincing evidence from many studies of people who were exposed to either arsenic-contaminated drinking water, arsenical medications, or arsenic-contaminated air in the workplace. The studies provide evidence of arsenic causing cancer for various exposure durations, ranging from a few years to an entire lifetime (ATSDR 2000). Of the different types of cancer from oral exposure, skin cancer—namely, squamous cell carcinoma and basal cell carcinoma—and other types of cancer, including cancer of the lungs, bladder, kidney, liver are a concern.

There are different ways to evaluate whether the arsenic soil levels at VBI70 have the potential to cause cancer among exposed individuals. One way is to compare the exposure doses for the VBI70 study area to the exposure doses that have been reported in the literature to increase cancer in humans. Using this approach, people who live all or most of their life in homes in the VBI70 study area with the most highly contaminated yards and who are in the highest bracket for soil ingestion have estimated exposure levels to arsenic that are similar to exposure levels that have been shown in human studies to cause cancer (ATSDR 2000.) This conclusion applies to about 40 properties with average arsenic levels above 300 ppm and is based on the following assumptions:[19]

- someone grows up in a home with a yard that is highly contaminated,
- an adult lives in a home for several decades with a yard that is highly contaminated, and
- someone who is in the higher soil intake bracket.

It is important to realize that ATSDR is not proposing 300 ppm as a clean-up number or action level but is emphasizing the seriousness of potential arsenic exposure levels at many of the more highly contaminated properties.

Another way to evaluate the cancer-causing potential from arsenic in soil is to use mathematical

[18] It should be noted that the highest level of arsenic in soil detected at the VBI70 site was about 16,000 ppm.

[19] The assumptions used to reach this conclusion are that preschool children ingest 200 milligrams of soil a day and older children and adults ingest 100 milligrams of soil each day. ATSDR also assumed a 60% bioavailability and exposures of several decades up to lifetime.

estimates of cancer risk based on estimated arsenic exposure over many years. EPA typically uses this approach to estimate a potential increased risk of cancer from estimated exposure doses. A key parameter in this calculation is the cancer slope factor, which, for arsenic, was derived from arsenic exposures and skin cancer cases reported in the Taiwan study (Tseng et al. 1968, ATSDR 2000.) Applying this mathematical method to the VBI70 study area, ATSDR estimated doses for exposure scenarios ranging from 30 to 70 years, 40 and 60 percent bioavailability, people with average soil intake, and people with high soil intake. Based on these estimated doses, the mathematical model suggests that a significant potential increase in cancer risk might exist for long-time residents at many of the properties that were sampled as part of Phase III.

For people with high soil intake, the cancer risk at the more highly contaminated properties ranges from about 3 extra cases per every 10,000 people exposed to about 20 extra cases for every 10,000 people exposed for a lifetime to arsenic in soil.

When applying this cancer risk to the VBI70 study area, which contains 13,000 people, it is wrong to conclude that one might expect to see 20 or so arsenic-induced cancers for the 13,000 people who live in the VBI70 study area. The reason for this is that most properties in the VBI70 site are not contaminated with arsenic; therefore, most of the people are not exposed to high arsenic levels. In addition, the estimated number of cancers is based on a relatively small group of people in the high soil intake bracket. To put in perspective the cancer risk of 3 to 20 extra cases of cancer for every 10,000 people exposed, one needs to realize the following points.

- Of the approximately 3,000 properties sampled so far by EPA, a relatively small number of properties have elevated levels of arsenic in soil, probably on the order of several hundred properties.

- Somewhere between 37 and 57 percent of the people in Clayton, Cole, Elyria, Swansea, and Southwest Globeville move within 5 years (see Appendix D, Table D-2); therefore, a significant portion of the potentially exposed population may not get exposed for a lifetime.

- However, some people may move to another property in the VBI70 study area or to another property in Denver that is contaminated with arsenic, which would result in continued exposure to arsenic.

- Somewhere between 14 and 20 percent of the people in Clayton, Cole, Elyria, Swansea, and southwest Globeville live in their homes more than 30 years (see Appendix D, Table D-2); therefore, a relatively small, but significant, portion of the potentially exposed population may have close to lifetime exposure.

ATSDR notes also that there is some uncertainty in the mathematical estimate of cancer risk for several reasons:

- The mathematical model is based on cancers observed at certain exposure levels to arsenic. The model then assumes that cancers will occur at lower levels of exposure, even though this has not been supported or rejected by actual studies. It is possible, but again not proven, that the human body can eliminate arsenic at low exposure levels before it has its cancer causing effect. If this were true, the mathematical model would overestimate the theoretical risk of cancer.

- The mathematical model, at least for arsenic, is based on a key input from the Taiwan study. This input is somewhat uncertain, because the exposure doses for this population were estimated and not measured. In addition, the people in the Taiwan study might have been exposed to arsenic via pathways other than drinking contaminated water; if true, this would bias the key input to the mathematical model and overestimate cancer risk.

- Some researchers have suggested that the cancer incidence observed in the Taiwan study does not apply to the U.S. residents, due to nutritional differences between these populations (ATSDR 2000).

- Soil ingestion might be less in winter when people spend more time indoors compared to summer when people tend to spend more time outdoors.

In addition to the uncertainties listed above, some scientists believe that the mathematical model is inherently flawed. Specifically, they believe that exposures to small amounts of arsenic are safe if they are lower than a "threshold dose" for cancer. These scientists suggest that exposure to small amounts of arsenic might not cause cancer (Stöhrer 1991; Abernathy et al. 1996).

In support of the cancer-causing potential for arsenic in the environment, the National Research Council recently concluded that there is little evidence to support a threshold for arsenic carcinogenesis and noted that nutritional status and arsenic exposure from other sources in the Taiwanese studies would have only modest impact on cancer risk estimates derived from using the Taiwanese data. It should be noted that cancer studies from other countries, such as Chile, India, and Bangledesh support the cancer estimates derived from the Taiwanese studies.

Despite these uncertainties, the two different approaches for evaluating whether highly contaminated arsenic soil levels in the VBI70 study area might cause cancer yield similar conclusions that arsenic levels in soil at some properties are a public health concern for cancer. The common finding is that people who live in homes with the most highly contaminated yards in the VBI70 study area for many decades might be exposed to arsenic at levels that increase their risk of cancer.

Homeowners who refused soil clean up

As mentioned earlier in this report, the owners of six properties in the VBI70 study refused to allow EPA access to clean up arsenic-contaminated soil at their homes. The soil arsenic levels at these properties could cause harmful effects in some soil-pica children, preschool and elementary school children who live at these homes or who visit them and have typical soil intakes.

ATSDR plans to talk to these residents to inform them of the health risks involved with soil arsenic contamination in hopes of convincing them to allow EPA access to clean up their yards. ATSDR also plans to talk to EPA, state, and local agencies about a notification system for these properties.

Arsenic levels in the Northeast Park Hill neighborhood

High levels of arsenic have been found in some yards in the Northeast Park Hill neighborhood, a residential area east of the VBI70 study area that is not part of the NPL site. The limited number of soil samples from the properties sampled do not allow ATSDR to evaluate long-term exposure to arsenic. However, the results show that some properties are likely to have significant arsenic contamination. For instance, the four samples from one property on Glencoe all had significantly elevated arsenic. In addition, high levels of arsenic in soil were found in some properties that could cause harmful effects in some children with soil-pica behavior. It is difficult to be certain about the degree of the health threat for soil-pica children in the properties sampled because the limited number of samples do not allow ATSDR to know the true maximum arsenic level. The high frequency of significantly elevated arsenic levels in the 36 properties sampled leads ATSDR to believe that many homes in the Northeast Park Hill neighborhood have areas in their yards with high levels of arsenic contamination that could be harmful to children, especially children with soil-pica behavior.

Possible Health Effects from Exposures to Lead

ATSDR also evaluated whether residents of the VBI70 study area were or are being exposed to lead in soils at levels that might be associated with adverse health effects, both for cancer and non-cancer effects. Regarding cancer effects, the weight-of-evidence from a large number of studies of lead exposure in humans has yet to establish a clear link between lead and cancer. Given the vast amount of research conducted on lead-related health effects, this lack of evidence suggests that lead is a very weak carcinogen in humans, if at all. Therefore, exposures to lead in the soils in the VBI70 study area likely do not cause additional cancers among residents. Further, the many studies on the toxicity of lead have shown that children are most susceptible to adverse health effects following exposures, and environmental exposures among adults generally do not result in as serious effects. As a result, the remainder of this section focuses on non-cancer effects that might occur in children following exposures to lead.

Residents of the VBI70 study area can be exposed to lead in soil in the same manner that they can be exposed to arsenic in soil—that is through ingestion by hand to mouth activity. As noted earlier, preschool children have the greatest amount of exposure because they frequently touch soil and touch their mouths. In addition, soil-pica behavior can also result in excessive exposure to lead. Other sources of lead could also exist in the VBI70 study area that might add to the lead exposure that comes from contaminated soil. These other sources include lead-glazed pottery as well as lead-based paint in homes, especially since roughly 80% of homes built in the U.S. before 1978 are believed to still contain some lead-based paint (CDC 1985, 1991). Older homes not only are more likely to have lead-based paint, but also are more likely to have higher concentrations of lead in their paint. Housing built before 1950 that has not been resurfaced poses the greatest risk for children being exposed to lead from paint (CDC 1985, 1991). In the VBI70 site, about 60% of the homes were built before 1950, while about 80% of the homes were built before 1978, the year lead-based paints were banned for home use (see Appendix D, Table D-1 for more details.) In addition, children can also be exposed to lead through their diets, eating food from lead-containing ceramics, using certain traditional medical remedies, and from some parents' occupation and hobbies (CDC 1985, 1991). Therefore many sources of lead often exists in a child's environment, including lead-contaminated soils.

Different investigators have found widely varying relationships between soil and dust lead levels and children's blood lead levels. Based on a review of other investigators, the Centers for Disease Control and Prevention (CDC) reports that blood lead levels generally rise 3 to 7 micrograms per deciliter (μg/dL) for each increase of 1,000 ppm of lead in soil or dust (CDC 1991, EPA 1986, Bornschein et al. 1986, ATSDR 1988). The CDC has established a blood lead level of 10 μg/dL (10 micrograms of lead per deciliter of blood) as a level of concern.[20] CDC established this value after evaluating a large number of rigorous epidemiologic and experimental studies. In particular, recent human studies have provided new evidence about the association between low-level lead exposure and child development (CDC 1991). CDC states that blood lead levels that exceed 10 μg/dL are associated with decreased intelligence and impaired neurobehavioral development. Many other effects begin at these low blood lead levels, including decreased stature or growth, decreased hearing, and decreased ability to maintain a steady posture, and become more pronounced at higher blood lead levels. Lead's impairment of the synthesis of vitamin D is detectable at blood lead levels of 10 to 15 μg/dL.

The concern at the VBI70 site is what contribution lead in soil will make to a child's blood lead level that is already affected by other sources of lead. Because children's play habits and hand-to-mouth activity vary, the contribution that lead in soil makes to a child's blood lead level most likely varies. This variation makes it very difficult to decide for an individual child how much lead in soil is actually getting into a child's blood. Therefore, lead levels in soil must be evaluated in a more general sense.

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[20] A deciliter equals 100 milliliters (ml) or about 3 ounces.

EPA has developed a mathematical model that uses the average soil lead levels in a property to predict the percentage of children with blood lead levels above the Centers for Disease Control and Prevention's (CDC) level of concern of 10 micrograms lead per deciliter of blood ($\mu g/dL$). For the VBI70 site, EPA's model predicts a range of soil lead levels that could result in more than 5% of the children having blood lead levels greater than 10 $\mu g/dL$. The range of soil lead levels predicted by the model vary because EPA varied certain input parameters in the model (specifically, the geometric standard deviation and dietary lead intake). The model predicted that soil lead levels ranging from as little as 208 ppm to as much as 540 ppm as being a concern for increasing blood lead levels in children depending upon which input parameters most accurately predict blood lead levels. It should be noted that 78 properties have average lead levels in soil higher than 540 ppm while about 1,350 properties have average soil lead levels higher than 208 ppm.

Site-specific conditions, such as, amount of bare soil, children's play areas, chemical form of lead, how much lead crosses the gut, and particle size could affect blood lead levels and the possibility of harmful effects occurring. It should be noted that EPA cleaned up four properties in 1998 with average lead levels greater than 2,000 ppm.

The elevated levels of lead in soil in some properties in the VBI70 site along with lead from other sources increases the risk in some preschool children for having increased levels of lead in their blood. At blood lead levels slightly above 10 $\mu g/dL$ the following health effects might occur in affected children:

- neurobehavioral effects, such as decreased intelligence or delays in development,
- impaired growth (decreased stature),
- endocrine effects, most commonly altered vitamin D metabolism,
- blood effects, such as changes in blood enzyme levels, and
- decreased performance on hearing tests.

These lead-related effects are documented in several population studies that investigated the harmful effects of lead (e.g., ATSDR 1999; CDC 1991). The effects are difficult to identify in individuals with blood lead levels between 10 and 20 $\mu g/dL$ because the effects are subtle changes. The effects can be detected, however, when large groups of children are studied.

Since limited blood lead measurements have been conducted on children who live at the VBI70 site, the exact extent to which soil contamination might have contributed to their blood lead levels or caused harmful effects is not known. In summer 2000, the Colorado Department of Public Health and Environment (CDPHE) offered voluntary blood lead testing at several locations in the VBI70 site as part of their state-wide lead poisoning prevention program. This program targets children who are not covered by Medicaid. In addition, as recent as September 25, 2000, at Saint Martin's Plaza and October 3, 2000, at Harrington Elementary School, CDPHE offered lead testing for children. Of the 86 children that participated, 8 had blood lead levels that exceeded the CDC's level of concern of 10 $\mu g/dL$ with the highest level detected being 18 μg/dL. The age of the children ranged from 7 months to 6 years. Finding this many blood lead levels above CDC's 10 μg/dL shows that a significant blood lead concern is likely to exist for children living in the VBI70 study area.

In evaluating public health issues concerning children and lead, it is important to remember that children get exposed to lead from many sources. In addition to lead coming from soil, children also get exposed to lead from other sources. Here are a few examples:

- lead in a child's diet,
- lead in drinking water,
- lead from leaded paint,
- lead from lead-glazed pottery,
- other unidentified sources.

CDPHE has a state-wide blood lead program that tests children for blood lead. For more information about CDPHE's blood lead program, contact Ms. Mishelle Macias at 303-692-2622. In addition, the Denver Department of Environmental Health (DEH) within the City and County of Denver is responsible for responding to lead issues. DEH's program is managed by Mr. Gene Hook, who can be contacted at 720-865-5452. DEH follows CDC guidelines, and when a child with elevated blood lead is referred, DEH will conduct an environmental investigation to identify potential sources of lead. Typically, the investigation includes collecting environmental samples from the home environment and administering a questionnaire designed to identify lead sources. DEH also provides the family with information about the health effects of lead, ways to prevent exposure to lead, proper nutrition, access to other relevant services, and the need for follow up blood tests.

CDC states that blood lead levels below 10 μg/dL are not considered to indicate lead poisoning. CDC considers children with blood lead levels between 10 and 14 μg/dL to be in a border zone. CDC does not recommend a home inspection when children are found at these levels because CDC states that it is unlikely that a single predominant source of lead exposure can be found for most of these children. CDC states, however, that it is prudent to try and decrease exposure to lead with some simple instructions and to conduct a follow-up blood lead test in 3 months. CDC states that the adverse effects of blood lead levels between 10 and 14 μg/dL are subtle and are not likely to be recognizable or measurable in the individual child (CDC 1991).

CDC states that when children have venous blood lead levels of 15 to 19 μg/dL, careful followup is warranted. A health care provider or appropriate health official should take a careful history to look for sources of lead exposure, and parents should receive guidance about interventions to reduce blood lead levels. CDC states that children with blood lead levels between 15 and 19 μg/dL are at risk for decreases in intelligence of up to several IQ points and other subtle effects (CDC 1991).

Discussion of Community Concerns and Questions

ATSDR staff members met with community representatives many times and with residents at an availability session held in the VBI70 study area where they had the opportunity to talk with ATSDR employees, either one-on-one or in small groups. Residents asked ATSDR to address several health and environmental questions. These questions are listed below with ATSDR's responses (shown in italics). In some cases, questions were referred to the appropriate federal, state, or local agency for a response.

1. *How can residents reduce exposure to contaminants in their yard?*

   The VBI70 health team developed a fact sheet that responds to this question (see Appendix I). In general, residents can take the following simple steps to reduce exposure to contaminants in soil:

   - washing hands frequently
   - removing shoes before entering homes
   - washing fruits and vegetables thoroughly
   - washing dogs
   - cleaning floors with damp mops
   - cleaning counters and furniture with damp dust rags

2. *Are communities of color at increased risk of harmful effects from lead and arsenic exposure?*

   No evidence exists to show that African-American or Hispanic communities are more or less sensitive than other groups to arsenic and lead because of their genetic make-up.

   Some factors that might increase someone's sensitivity to arsenic are listed here:

   - poor nutrition,
   - low levels of chemicals (antioxidants) in the blood that protect the body's cells from damage,
   - iron deficiency,
   - decrease in the body's ability to metabolize arsenic,
   - differences in the enzyme glutathione S-transferase,
   - differences in the enzymes that repair damage to chromosome (DNA) (Chen 2000).

In addition to the issue that some people are more sensitive to the effects of arsenic as previously described, some difference exists in the distribution of contamination in the neighborhoods. Specifically, more homes in Elyria, a predominantly Hispanic neighborhood, and Cole, a predominantly African-American neighborhood, have yards with elevated levels of lead in soil compared to Swansea and Clayton. This conclusion is shown in the lead distribution maps that appear in Figures 10 and 11.

One possible explanation for more frequent lead contamination in Elyria and Cole is that fallout from one of several nearby smelters has raised lead levels in surface soil. Another possible explanation is that the homes in the western portion of the site are older and therefore more likely to have lead paint on the exterior. The implication is that years of weathering and chipping has contaminated the yards. This explanation seems unlikely since the percentage of older homes (for instance, homes built before 1950 when high amounts of lead were commonly added to paints) is very similar in Elyria and Cole compared to Swansea and Clayton (see Appendix D, Table D-1.)

3. *What do the technical environmental and health terms used during the health team meetings mean?*

   The community representatives asked that government officials be aware that they might not understand the technical terms and government jargon that is frequently used when talking about the VBI70 site. ATSDR staff members and other government officials worked with community members during the health team meetings to limit the use of technical terms. When technical terms had to be used, they were defined for the team members. ATSDR staff members had several meetings with community representatives to help them understand the technical terms and the process used to make public health decisions. A glossary of environmental and health terms is provided in Appendix J.

4. *Community representatives would like to have technical assistance in developing and presenting messages to the community. Community representatives also want to set up the meetings with the community.*

   Agency members of the VBI70 health team agreed to help community representatives with technical issues and agreed that community representatives should be an integral part of planning community meetings. Further, Agency members agreed to help community representatives develop and present messages to the community. For example, when ATSDR released its fact sheet on gardening in the VBI70 study area, ATSDR staff members worked with community members to develop the fact sheet and to set up community meetings for the residents to answer questions about gardening. ATSDR also worked with community representatives as they wrote and used parts of the fact sheet in the newsletter for Swansea and Elyria.

5. *Community representatives reported that there is an old landfill in the Clayton neighborhood and suggested that someone provide more information in writing to the community about the landfill. Some issues about this landfill are [A] its location, [B] when it was last active, [C] whether environmental data are available on the landfill, and [D] whether it can be monitored. One community representative said that Adams Street in the Clayton neighborhood was built on top of the landfill. Community members stress that it is important that the information be in writing.*

    Ms. Barbara O'Grady, the site lead for CDPHE, said that CDPHE will respond to this issue. Ms. O'Grady said that Mr. Glenn Malloy (303-692-3445) or Mr. Peter Laux (303-692-3455) with CDPHE's Solid Waste Unit might have answers about the landfill. Also, Ms. Celia VanDerLoop (City and County of Denver) said that she may also have information about landfills in the neighborhoods.

6. *What industrial processes are currently going on at the ASARCO facility in Globeville? Community representatives would like to have an explanation of the chemical processes involved, particularly as it relates to emissions. There is a question about what is meant by a process for high purity metals.*

    During ATSDR's investigation, ASARCO officials hosted a site tour of its Globe facility to allow government officials and community representatives to become familiar with the facility's operations. In addition, ATSDR learned from ASARCO representatives that the facility currently produces bismuth products,[21] litharge,[22] highly purified lead, and tellurium.[23] Small amounts of highly purified "specialty metals" are also produced. Specialty metals produced during the last year include cadmium telluride, cadmium sulfide, lead telluride, zinc telluride, and high purity copper cylinders. ASARCO did not provide information to ATSDR about what is emitted by the facility.

7. *Community representatives asked several questions about why non-cancerous health effects were increased in the community. Examples of non-cancerous effects include asthma, respiratory (lung) diseases, skin rashes, thyroid disease, kidney disease, stomach problems, children in remedial/special education classes, and retarded children. Community representatives also expressed concern about there being a two-fold increase of cancer of the larynx and kidney in the community and an increase in leukemia.*

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[21] Bismuth is a metal, like lead and arsenic, and is used in making pharmaceutical products (for example, Pepto Bismol). It is also used in industrial processes.

[22] Litharge is an oxide of lead made by heating metallic lead.

[23] Tellurium is a nonmetallic element, similar to sulfur. It has a number of industrial uses, for example, as part of stainless steel and iron castings and as a coloring agent in glass and ceramics.

No data are available to confirm whether non-cancerous effects mentioned are greater than expected for this part of Denver. Decisions about whether or not to determine cancer and non-cancerous disease rates for the VBI70 study area will be made at a later date.

The Cross Community Coalition has applied for a grant from the federal National Institute of Environmental Health Sciences to investigate the status of adverse health effects in the community. Information from this investigation will be useful in answering some of the previous questions.

8. *The community wants to be educated so they will know what questions to ask their doctors based on the health effects that might occur from exposure to contaminants in soil. Community representatives would also like the VBI70 health team to educate doctors so they know what to look for and would be willing to test for certain effects.*

   The CDPHE has a cooperative agreement with ATSDR to conduct health education in the community. The agencies are working with community representatives on these issues. For instance, a letter to physicians and other health care providers is being drafted to inform them of the VBI70 site and its associated hazards. As part of ATSDR's environmental health interventions project, ATSDR staff members will be working with a local clinic and with community representatives to educate people about the adverse health effects from arsenic and lead. In addition, when the public health assessment is released, ATSDR staff members will hold public meetings to talk to residents about the report and to answer their questions as well as holding a press release and talking with news media. As the agencies continue to work together with community representatives, other activities may also be started.

9. *How was 70 parts cadmium per million parts soil (70 ppm cadmium) established as a clean-up level for Globeville?*

   Since CDPHE developed the 70 ppm cadmium clean-up number for the Globeville ASARCO site, ATSDR has referred this question to CDPHE staff members.

10. *Other questions: The community members asked ATSDR several questions and raised some concerns that are more appropriate for EPA to address and not for ATSDR to address. In a letter dated March 24, 1999,(see Appendix K), ATSDR informed EPA of these questions, which are listed below:*

    - A better understanding is needed of the sampling methods EPA used at the VBI70 site. More specifically, what is the difference between a composite versus an average and how will the difference between the two be used in EPA's risk assessment?
    - Why did EPA not sample for cadmium and zinc?

- Why were certain houses deleted from the list of houses for emergency cleanup?
- A better understanding is needed of EPA's risk assessment process.
- What is the meaning of environmental and health terms that might be used during workgroup discussions?

In 1999, EPA responded to these questions during its monthly meetings with the community representatives.

Discussion of Health Outcome Data

Completed Medical testing

During its 1998 Phase II investigation, EPA identified 21 properties that required immediate clean-up because soils at these properties had either high levels of arsenic (greater than 450 ppm) or high levels of lead (greater than 2,000 ppm). To characterize potential exposures, EPA offered to collect and analyze blood, hair, and urine samples from the residents of these properties, at no cost to the residents. Overall, EPA contacted 69 residents from 17 of the 21 properties of concern, but only 15 residents from six properties volunteered to participate in EPA's biological survey. These 15 residents included nine adults, five children or teenagers, and only one preschool child. This breakdown of the surveyed population is important, since the group most likely to be exposed, preschool children, were not tested.

EPA performed three types of measurements on the biological samples that were collected from the15 residents. A summary of the survey's findings follows:

Arsenic in urine

EPA reported that no arsenic was detected in the urine of people tested, and the detection limits in this study ranged from as low as 10 micrograms per liter (μg/L) to greater than 50 μg/L. Of the urine samples collected during the survey, five had undesirably high detection limits—greater than 50 μg/L—which limits the usefulness of these samples. The five participants refused to provide additional samples. The results of the remaining urine samples showed that the residents did not have excessive exposure to arsenic at the time the survey was conducted. ATSDR does not believe, however, that this finding means that levels of arsenic in the soil at the properties were safe. The reasons for reviewing the conclusion with caution follow:

- participants came from only six of the 21 properties with high levels of arsenic, and only 15 out of at least 69 eligible residents participated. This level of participation is too low to represent all the people in the VBI70 study area,
- only one preschool child, the group most likely to be affected by soil contamination, was tested,
- samples were collected in late fall or early winter, when outdoor activities (and presumably exposures) would be lower than in the summer,
- samples were collected at only one point in time, thus providing only a "snapshot" of exposures over the long term, and

- the extent of arsenic contamination in some yards was not known because some yards had only a few soil samples.

Arsenic in hair

EPA also measured arsenic levels in hair samples from the 15 participants. In general, arsenic can become part of human hair by different processes. For example, arsenic that is absorbed into the body can become part of newly made hair as it grows, thus arsenic levels in parts of the hair represent exposure over the growth period of the hair. In addition, arsenic in the external environment can bind directly to hair upon contact. For instance, arsenic in sweat can become bound to hair and arsenic in dusts in the environment can settle onto hair and be transferred directly to hair. When measuring hair arsenic levels, however, it is impossible to know how the arsenic got there, which complicates efforts to interpret the meaning of arsenic levels in human hair. In EPA's survey, only one hair sample had detectable levels of arsenic, and its concentration was 0.41 ppm. The remaining 14 hair samples did not have detectable levels of arsenic. Two of these samples had undesirably high detection limits, but the subjects refused to provide additional samples. Overall, the hair samples suggest that elevated exposures of arsenic did not occur among the subjects, but, for the reasons listed previously, these findings are not convincing.

Lead in blood

EPA also measured blood lead levels in some residents. The concentrations of lead in the 15 blood samples ranged from 1 to 4 μg/dL (deciliter)[24], and the geometric mean concentration for the 15 samples was 2.2 μg/dL. For reference, a national survey found that the geometric mean concentration for blood lead was 2.8 μg/dL for people aged 1 to 74 years (CDC 1991, ATSDR 1999). Moreover, all of the blood lead levels measured by EPA are lower than 10 μg/dL—the level that the Centers for Disease Control and Prevention (CDC) has established as a guideline for deciding when actions should be taken to reduce blood lead levels. When levels are lower than 10 μg/dL, CDC recommends that no actions be taken. Therefore, the blood lead results from EPA's biological sampling survey shows that excessive exposure to lead did not occur at the time of testing. However, for the reasons cited previously, ATSDR does not think these results can be used to draw conclusions about the safety of soil lead levels at the VBI70 site.

In summer 2000, the Colorado Department of Public Health and Environment offered voluntary blood lead testing at several locations in the VBI70 site as part of their state-wide lead poisoning prevention program. As recent as September 25, 2000, at Saint Martin's Plaza and October 3, 2000, at Harrington Elementary School, CDPHE offered lead testing for children. Of the 86 children that participated, 8 had blood lead levels that exceeded the Centers for Disease Control and Prevention's level of concern of 10 micrograms lead per deciliter (10 μg/deciliter). The age of the children ranged from 7 months to 6 years.

[24] A deciliter is 100 milliliters, which is about 3 liquid ounces.

The CDPHE did not find a relationship between blood lead results and lead levels in soil but too few children were tested to conclude whether or not soil lead levels are contributing to blood lead levels. For more information about CDPHE's blood lead program, contact Ms. Mishelle Macias at 303-692-2622.

CDC states that blood lead levels below 10 μg/dL are not considered to indicate lead poisoning. CDC considers children with blood lead levels between 10 and 14 μg/dL to be in a border zone. Therefore, many of these children may have blood lead levels that are below 10 μg/dL. CDC does not recommend a home inspection when children are found at these levels because CDC states that it is unlikely that a single predominant source of lead exposure can be found for most of these children. CDC states, however, that it is prudent to try and decrease exposure to lead with some simple instructions and to conduct a follow-up blood lead test in 3 months. CDC states that the adverse effects of blood lead levels between 10 and 14 μg/dL are subtle and are not likely to be recognizable or measurable in the individual child (CDC 1991).

CDC states that when children have venous blood lead levels of 15 to 19 μg/dL, careful followup is warranted. A health care provider or appropriate health official should take a careful history to look for sources of lead exposure, and parents should receive guidance about interventions to reduce blood lead levels. CDC states that children with blood lead levels between 15 and 19 μg/dL are at risk for decreases in IQ of up to several IQ points and other subtle effects (CDC 1991).

On-going medical tests

EPA has offered urine arsenic, hair arsenic, and blood lead testing to anyone in the VBI70 study whose property was tested as part of Phase III. To be tested, residents were given a voucher that allowed them to go to the Centra Clinic in Globeville for testing. The EPA has informed ATSDR that a small number of people have been tested, but they have not shared those data with ATSDR because of confidentiality issues.

ATSDR is working with CDPHE and the University of Colorado to develop a plan to collect biological samples from residents of the VBI70 study area. In addition, ATSDR is considering ways to identify soil-pica children and ways to access their health.

Discussion of Other Activities

ATSDR and EPA Efforts to Evaluate Past Human Studies and Arsenic Toxicity

When evaluating soil arsenic levels at the VBI70 site, ATSDR raised concerns about acute arsenic exposure (exposures for just one time or for a few days) in children with soil-pica behavior. Since EPA did have a health guideline for evaluating this exposure scenario, EPA proposed in October 1999 that the two agencies jointly evaluate human studies for acute (less than two weeks) and subchronic (two weeks to 7 years) exposures to arsenic. The purpose of this effort is to identify the most appropriate human studies for evaluating acute and subchronic exposures to arsenic. The workgroup has completed its task and EPA is developing a report that summarizes the findings. The purpose of this effort is intended to ensure a consistent approach between ATSDR and EPA at the VBI70 site and at other sites where arsenic is a contaminant of concern from acute and subchronic exposures.

Health Education and Promotion at the VBI70 Site

When investigating hazardous waste sites, ATSDR often recommends and conducts health education and community involvement activities prior to the release of a public health assessment and other site-related reports. In the case of VBI70, ATSDR is working cooperatively with CDPHE to conduct important health education activities. Some activities have already been completed and additional activities are planned to educate health care providers.

As previously noted, an important health education activity for the site started with the ATSDR-CDPHE joint evaluation of the safety of gardening in the VBI70 study area. Based on this evaluation, the health team members developed two fact sheets describing safe gardening practices and outlining the results from the evaluation (see Appendices E and F). The fact sheets were distributed in both English and Spanish to residents around the VBI70 site and were printed in a community newsletter, which was sent to approximately 2200 residents. Additionally, the group held two public availability sessions at the Herrington Elementary School and the Swansea Community Center in April 1999. During these meetings, residents were able to ask public health specialists questions regarding the safety of gardening and to receive gardening tips from a horticulturist from the University of Colorado. Additionally, ATSDR has prepared and distributed an information sheet that outlines steps residents can take to protect their health and prevent exposure to contaminants in soil (see Appendix I). Ongoing activities, such as contacting local health care providers to introduce them to the VBI70 site, are in the early stages of development.

ATSDR's Child Health Initiative

To ensure that the health of the nation's children is protected, ATSDR implemented an initiative requiring that health assessments determine whether or not children are being exposed to site-related hazardous waste and whether or not the health of children might be affected.

This public health assessment reflects ATSDR's concern about protecting children's health from toxic chemicals in the environment. Specifically, whenever soil is a pathway of concern, as it is at the VBI70 site, children will have greater exposure to contaminants in soil than adults. As a result, a major focus of ATSDR's investigation at the VBI70 site was children's exposure to arsenic and lead in soil, and the potential health effects associated with this exposure. As noted throughout this report, evaluating exposures to children with soil-pica behavior had a strong influence on ATSDR's public health decisions. By examining high-end exposures among children in the VBI70 study area as well as exposures among children with soil-pica behavior, ATSDR has conducted a complete assessment of how contamination in the VBI70 study area might affect children's health.

Conclusions

Health hazard category

ATSDR has determined that soil arsenic levels at many but not all of the properties in the VBI70 study area are safe regardless of how much soil a child or an adult might ingest. ATSDR is concerned about soil arsenic levels in approximately 650 of the 2,986 properties sampled so far. ATSDR is concerned that these properties have arsenic levels in soil that might pose a public health hazard for soil-pica children who ingest unusually large amounts of soil. Based on EPA's baseline risk assessment, EPA has identified properties as a concern for children with soil-pica behavior if the property has an average arsenic level in soil of 47 ppm or greater. Based on demographic information, about 300 preschool children live in these 650 households and somewhere between 12 to 60 of these children might have soil-pica behavior some time during their preschool years. Depending upon the amount of arsenic contamination in these 650 properties and how much dirt soil-pica children ingest, the most likely health effects that might occur in soil-pica children include nausea, stomach cramps, vomiting, diarrhea, facial swelling, and headaches. No children have been diagnosed with arsenic poisoning in the VBI70 area that can be related to arsenic in soil; however, it is possible that cases could have been missed because the most likely symptoms (nausea, vomiting, etc.) are common symptoms in children that can result from a variety of causes.

Arsenic in soil at some properties is also a public health hazard for long-time residents because of the potential increased risk of cancer from arsenic exposure. This risk is greatest for children who grew up in yards with high levels of arsenic in soil and who continued to live their as adults. Some people who live at the more highly contaminated yards have estimates of arsenic exposure from soil that are similar to the levels in human studies that have been shown to cause cancer in people. Using a mathematical model developed by the EPA to quantitatively estimate cancer risk, a significant potential increase in cancer risk might exist for some long-time residents who live at the more highly contaminated properties. The EPA has identified about 260 properties where the increased risk of cancer is unacceptable. It should be noted that as of spring 2001, EPA has cleaned up about 50 properties so far because of elevated levels of arsenic in soil.

Uncertainty

Some uncertainty exists in deciding whether or not adverse health effects might occur. This uncertainty exists in two areas: estimating how much arsenic people are exposed to (that is, the dose) and determining the health effects that might occur. The uncertainty that exists in estimating the dose for soil-pica children comes from the following issues:

- estimating the maximum arsenic level in a property based on arsenic levels from three composite samples,
- variations in how much dirt soil-pica children eat, (for instance, ATSDR assumes that soil-pica children eat 5,000 milligrams of soil a day),
- variations in how often children exhibit soil-pica behavior,
- assuming that soil-pica children eat soil from the most contaminated part of the property, and
- uncertainty in the percentage of children with soil-pica behavior.

Therefore, a child with soil-pica behavior who lives at a property with arsenic-contaminated soil might not get sick if the child eats soil from an area in the yard with low arsenic levels; or, if the child eats only a small amount of soil, and the amount of arsenic exposure is not enough to cause health effects.

Uncertainty also exists in determining the health effects that might occur because of the following reasons:

- uncertain estimates of how much arsenic gets into the blood stream and tissues once soil-bound arsenic is ingested,
- assuming that the harmful effects observed in people exposed to arsenic in drinking water, which is readily absorbed by the body, is similar to the harmful effects that might occur in people exposed to arsenic bound to soil, which is likely to be less absorbed by the body.
- assumptions about the bioavailability of arsenic in drinking water and estimating the dose in human studies when drinking water is the source of arsenic, and
- variation in the amount of water that people drink and the accuracy of dose estimates in human studies that were used to develop health guideline values.

No children have been diagnosed with arsenic poisoning in the VBI70 area that can be related to arsenic in soil; however, it is possible that cases could have been missed because the most likely symptoms (nausea, vomiting, etc.) are common symptoms in children that can result from a variety of causes. A more detailed discussion of uncertainty can be found in the Discussion of the Public Health Significance of Contaminants Section.

Uncertainty also exists when determining the possible risk of cancer. These uncertainties include:

- the mathematical model used to estimate a quantitative risk assumes that the cancer risk is the same at low levels of exposure as it is at high level exposure,
- uncertainties exist in estimating the dose to Taiwanese people, the exposure group used to derive the model estimates,
- the cancer rates observed in the Taiwanese population might not apply to an American population because of nutritional differences,

- assuming a relatively high and constant soil intake for 30 to 70 years,
- constant soil intake during cold and warm weather, and
- occupancy at the same residence for 30 or more years.

ATSDR is planning a health investigation to learn more about soil ingestion in children at the VBI70 site. This health investigation will involve conducting a census of the community, surveying for soil-pica behavior, and conducting lead and arsenic testing of preschool children.

Lead contamination in the VBI70 site.

Certain properties in the VBI70 site are a public health hazard to some preschool children who live on properties with high lead levels in soil. Exposure to lead-contaminated soil at the more highly contaminated properties has the potential for increasing blood lead levels in some preschool children and might cause harmful effects involving the brain and nervous system. Possible effects include decreased intelligence, developmental delays, decreased stature, altered vitamin D metabolism, changes in blood enzyme levels, and decreased hearing.

EPA has developed a mathematical model that uses the average soil lead levels in a property to predict the percentage of children with blood lead levels above CDC's 10 micrograms lead per deciliter of blood (μg/dL). For the VBI70 site, EPA's model predicts that soil lead levels above 200 ppm might result in 5% of the children with blood lead levels greater than 10 μg/dL. About 1,300 properties in the VBI70 site have average soil lead levels higher than about 200 ppm.

Recent blood lead testing by CDPHE in summer 2000 found about 10% of the 86 preschool children tested with blood lead levels above CDC's level of concern of 10 μg/dL. It was not possible, however, to determine how much soil-lead contamination contributed to blood lead levels. For more information about CDPHE's blood lead program, contact Ms. Mishelle Macias at 303-692-2622. In addition to the state's efforts, the Denver Department of Environmental Health (DEH) within the City and County of Denver is responsible for responding to lead issues. DEH's program is run by Mr. Gene Hook, who can be contacted at 720-865-5452. DEH follows CDC guidelines, and when a child with elevated blood lead is referred, DEH will conduct an environmental investigation to identify potential sources of lead. Typically, the investigation includes collecting environmental samples from the home environment and administering a questionnaire designed to identify lead sources. DEH also provides the family with information about the health effects of lead, ways to prevent exposure to lead, proper nutrition, access to other relevant services, and the need for follow up blood tests.

Properties that refused clean up

Six property owners have refused to allow EPA access to clean up arsenic-contaminated soil These properties might be a health hazard to the current residents and to the families that might occupy those properties in the future.

Northeast Park Hill neighborhood

High levels of arsenic have been found in some yards in the Northeast Park Hill neighborhood, a residential area east of the VBI70 study area. The limited number of soil samples from the properties sampled do not allow ATSDR to evaluate long-term exposure to arsenic. The high frequency of significantly elevated arsenic levels in the 36 properties sampled leads ATSDR to believe that like the VBI70 site some homes in the Northeast Park Hill neighborhood have areas in their yards with high levels of arsenic contamination that could be harmful. Soil arsenic levels in some properties could be harmful to children with soil-pica behavior. It is difficult to be certain about the degree of the health threat in the properties sampled because the limited number of samples do not allow ATSDR to know the true maximum arsenic level.

The distribution of arsenic and lead

The distribution of lead in the VBI70 site shows that properties with elevated lead levels in soil are found more frequently in western portion of the site (that is, Elyria and Cole) than in the eastern portion of the site (that is, Swansea and Clayton.) This pattern of lead contamination indicates that more lead contamination might exist south and west of theVB170 area, and in the central industrial area inside the study area.

Since there was no obvious pattern for high levels of arsenic contamination, properties outside the study area might have significant levels of arsenic in soil. Low levels of arsenic from 12 to 30 ppm are more frequently found in Elyria, Southwest Globeville, and Cole, the western neighborhoods.

Five of the highest individual (discrete) lead levels in soil are found in three properties within 1,000 feet of the former Omaha-Grant smelter. This observation indicates that significant lead contamination might exist at and below the surface near the former smelter. Therefore, future investigations in this area should include collecting subsurface-soil samples since significant lead contamination may be below the surface.

As more environmental data become available, ATSDR will review those data to determine if the results affect decisions in this public health assessment and the public health activities at the Agency could undertake.

Recommendations

1. ATSDR's Division of Health Education and Promotion will continue to evaluate the VBI70 site for possible health education and health promotion activities. This process will include an evaluation of the health education activities that have been conducted to date and an assessment of the site for possible health education and promotion activities based on this evaluation.

2. ATSDR's Division of Health Studies is working with CDPHE and the University of Colorado Health Science Center to conduct a health investigation at the VBI70 site. The health investigation will (A) examine the occurrence of soil-pica behavior in preschool children, (B) offer urinary arsenic testing for children, (C) identify cases of acute and chronic arsenic and lead poisoning, and (D) conduct blood lead testing in preschool children.

3. EPA should reduce exposure to arsenic at properties with elevated levels of arsenic in soil so as to protect the health of children, especially children with soil-pica behavior, and to protect adults. Priority in reducing exposure should be given to properties with the highest arsenic levels where preschool children reside or are likely to play.

4. EPA should sample the approximately 1,000 properties in the VBI70 study area that were not sampled as part of the Phase III sampling round to determine if those properties have elevated arsenic and lead levels. Some of these properties are likely to have arsenic levels that are a public health threat to adults and children.

5. EPA should collect surface and depth soil samples from the area around the former Omaha-Grant smelter. The area sampled should extend at least 1,500 feet from the former smelter.

6. EPA should collect surface soil samples outside the VBI70 study area, starting with other neighborhoods in Denver. Specifically, soil samples should be collected south of the study area, that is, south of Martin Luther King Boulevard and Blake Street; west of the study area, that is, Fox Street; and east and southeast of the Clayton neighborhood. These samples should be measured for arsenic and lead.

7. EPA should collect soil samples from all residential properties in the Northeast Park Hill neighborhood to identify yards that have elevated levels of arsenic and lead in soil. EPA should reduce exposure to arsenic and lead at properties where high soil arsenic and lead levels have been detected.

8. EPA should collect surface and depth sediment samples from drainage ways in and around the VIB70 study area and from the South Platte River if that river was not adequately characterized for arsenic and lead as part of the ASARCO Globe Plant Site.

9. EPA, the Colorado Department of Public Health and Environment, and the City and County of Denver should develop a notification system for properties where EPA is not allowed to cleanup contaminated soil. The notification system should inform future occupants of those properties of existing arsenic or lead contamination in soil.

Public Health Action Plan

Completed Activities

Health education activities

During ATSDR's investigation, ATSDR and other members of the health team met and developed two gardening fact sheets (see Appendices E and F). The gardening facts sheets provided information to residents about the safety of gardening in the VBI70 study area. The gardening fact sheets were either mailed to residents or handed out at availability sessions that the health team held for residents in April 1999. As part of the availability session, health team members met with residents one-on-one to answer their questions about gardening and questions about the site. In addition, a flyer was given to residents showing them things they could do in their house and yard to reduce exposure to arsenic and lead in soil. A horticulturist from the University of Colorado answered questions about gardening in Denver.

Medical testing

During the public health assessment process, EPA offered residents who live at highly contaminated properties the opportunity for free medical testing to measure arsenic in urine, arsenic in hair, and lead in blood. Fifteen residents, including one preschool child, participated in the 1998 medical testing. Arsenic was not detected in urine or hair and blood lead results were at expected levels. However, for the reasons described previously in the Health Outcome Data section, these results cannot be used to decide if arsenic and lead in soil are at safe levels.

In summer 2000, the Colorado Department of Public Health and Environment offered voluntary blood lead testing at several locations in the VBI70 site as part of their state-wide lead poisoning prevention program. As recent as September 25, 2000, at Saint Martin's Plaza and October 3, 2000, at Harrington Elementary School, CDPHE offered lead testing for children. Of the 86 children that participated, 8 had blood lead levels that exceeded the Centers for Disease Control and Prevention's level of concern of 10 micrograms lead per deciliter (10 μg/deciliter). The age of the children ranged from 7 months to 6 years.

The CDPHE did not find a relationship between blood lead results and lead levels in soil but too few children were tested to conclude whether or not soil lead levels are contributing to blood lead levels. For more information about CDPHE's blood lead program, contact Ms. Mishelle Macias at 303-692-2622.

CDC states that blood lead levels below 10 µg/dL are not considered to indicate lead poisoning. CDC considers children with blood lead levels between 10 and 14 µg/dL to be in a border zone. Therefore, many of these children may have blood lead levels that are below 10 µg/dL. CDC does not recommend a home inspection when children are found at these levels because CDC states that it is unlikely that a single predominant source of lead exposure can be found for most of these children. CDC states, however, that it is prudent to try and decrease exposure to lead with some simple instructions and to conduct a follow-up blood lead test in 3 months. CDC states that the adverse effects of blood lead levels between 10 and 14 µg/dL are subtle and are not likely to be recognizable or measurable in the individual child (CDC 1991).

CDC states that when children have venous blood lead levels of 15 to 19 µg/dL, careful followup is warranted. A health care provider or appropriate health official should take a careful history to look for sources of lead exposure, and parents should receive guidance about interventions to reduce blood lead levels. CDC states that children with blood lead levels between 15 and 19 µg/dL are at risk for decreases in IQ of up to several IQ points and other subtle effects (CDC 1991).

On-going Activities

Local blood lead programs

In addition to the Colorado Department of Public Health and Environment's lead program for testing children, the Denver Department of Environmental Health (DEH) within the City and County of Denver responds to local to lead issues. DEH's program is run by Mr. Gene Hook, who can be contacted at 720-865-5452. DEH follows CDC guidelines, and when a child with elevated blood lead is referred, DEH will conduct an environmental investigation to identify potential sources of lead. Typically, the investigation includes collecting environmental samples from the home environment and administering a questionnaire designed to identify lead sources. DEH also provides the family with information about the health effects of lead, ways to prevent exposure to lead, proper nutrition, access to other relevant services, and the need for follow up blood tests.

Health investigations

ATSDR is working with CDPHE, the University of Colorado Health Science Center, and community representatives to conduct a health investigation to assess soil-pica behavior among preschool children and to identify household cases of acute and chronic arsenic and lead poisoning. The activities of the health investigation include the following:

- a community census to identify children at risk,
- exposure questionnaires to assess pica and soil ingestion behavior, and

- collection of urine and hair samples to measure arsenic and the collection of blood samples to measure lead.

These activities are scheduled to begin in spring 2002.

Health Education

ATSDR is also working with community representatives and other members of the health team to implement health education. Health education at the VBI70 site will include activities and materials that are specific to 1) the residents who live in the properties with the highest levels of contamination; 2) those residents with the greatest risk for exposure based on the results of the public health assessment, health study, and environmental interventions project; 3) residents who will participate in the interventions project and health study; 4) the general community living within the study area, and 5) health care providers.

- *Residents who live at the properties with the highest levels of contamination and residents with the greatest risk for exposure based on the results of ATSDR activities.*

  ATSDR will develop and implement health education activities designed to provide information regarding children's soil-pica behavior and general information regarding soil ingestion in children and adults. This information will provide ways that residents can reduce exposure to contaminants in their yards and reduce pica behavior.

- Information for residents about the public health assessment and for those residents who participate in the environmental interventions project, and health study.

- Information for health care providers about the VBI70 study area and adverse health effects from arsenic and lead exposure.

  ATSDR will develop health education materials for residents regarding the public health assessment and information for residents who participate in the interventions project and health study. The materials will explain the purpose of the activities, the process that will be used, and any limitations. ATSDR will also provide information to residents to assist them in understanding the information in these reports.

- *Health education to the community*

  ATSDR will provide information to residents in the VBI70 study area regarding ways adults and children can reduce exposure to possible contaminants in their soil. This information may be provided by A) publishing information in community newsletters, B) mailings to residents, and C) handouts during community meetings.

- Evaluation of ATSDR's activities at the VBI70 site.

  Working very closely with residents in each of the groups mentioned previously, ATSDR will identify their questions and health concerns prior to implementing health education activities at the site. After conducting health education, ATSDR will followup with residents to ensure that their questions and issues have been addressed and to measure the short and long-term impacts of the health education activities.

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Appendix A

List of VBI70 Health Team Members

List of VBI70 Health Team Members

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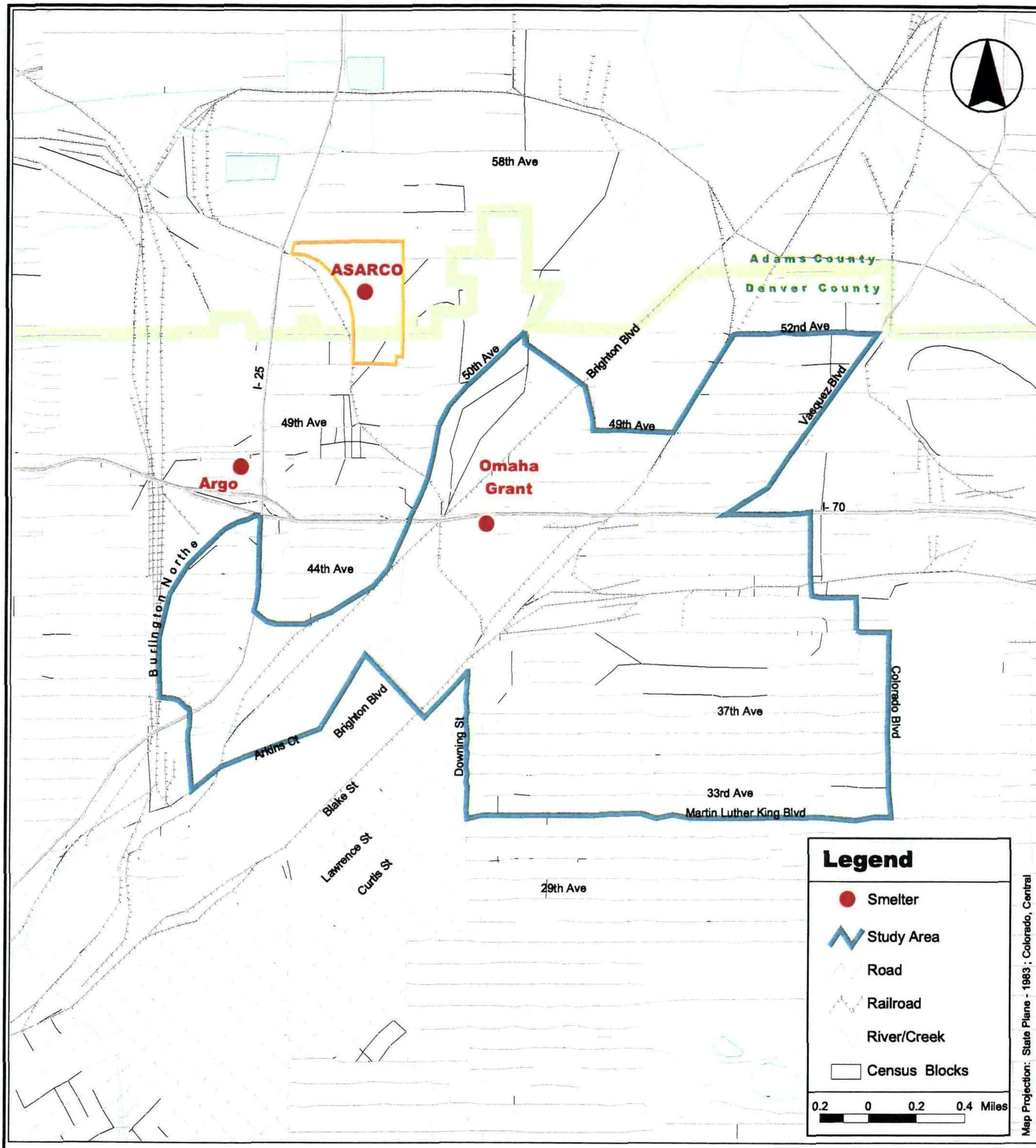
Appendix B

Figures 1 through 23



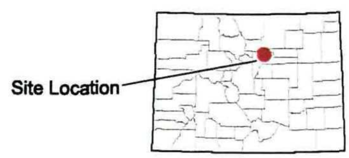
Study Area Boundary
Vasquez Boulevard/I-70 Site

Denver, Colorado

CERCLIS No. CO0002259588

VICINITY MAP

Base Map Source: 1995 TIGER/Line files, U.S. Census



Denver County, Colorado

ATSDR SAAGIS

MAM 09281999

Figure 1

Figure 2.

Timeline of ATSDR's

Public Health Assessment Activities

for the VBI70 Site, Denver, Colorado

Spring 2002 — **ATSDR releases final public health assessment**

Early 2002 — **ATSDR releases draft public health assessment to public**

December 2001 — **ATSDR releases draft public health assessment to federal, state, and local agencies**

2001 — **ATSDR evaluates environmental data and drafts public health assessment**

March 2001 — **ATSDR releases soil-pica report**

Summer/Fall 2000 — **ATSDR conducts health education activities**

June 2000 — **ATSDR sponsors soil-pica workshop**

Summer 2000 — **ATSDR begins environmental health intervention project**

August 21, 1999 — **Health team releases second gardening fact sheet**

April 26-27, 1999 — **Health team holds availability session for residents to discuss gardening**

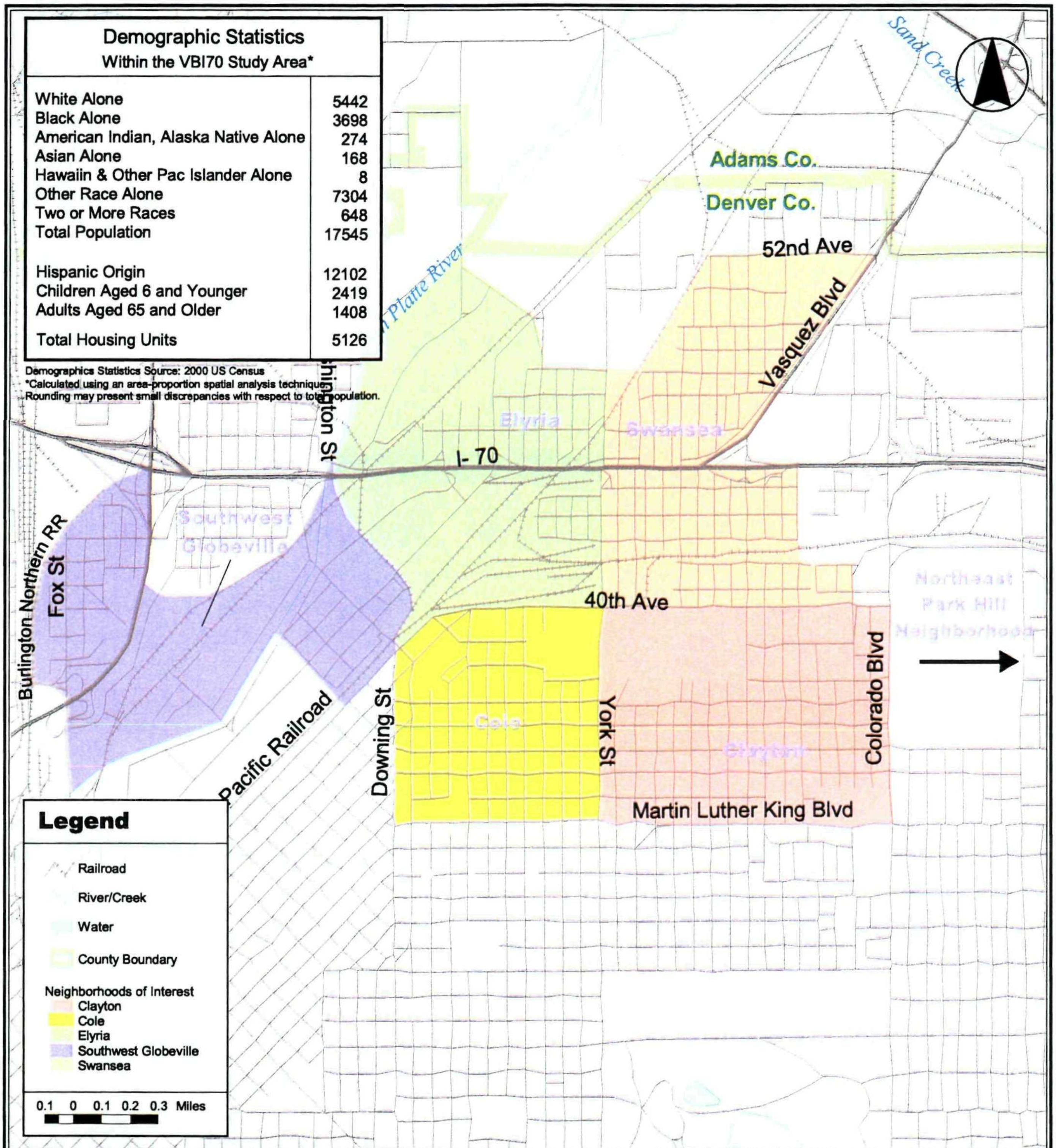
April 1999 — **CDPHE releases gardening fact sheet**

January 1999 — **ATSDR forms health team**

Winter 1998 — **ATSDR gathers community concerns**

Winter 1998 — **ATSDR begins health education activity**

Fall 1998 — **ATSDR contacts community members and agencies**



Demographic Statistics
Within the VBI70 Study Area*

White Alone	5442
Black Alone	3698
American Indian, Alaska Native Alone	274
Asian Alone	168
Hawaiin & Other Pac Islander Alone	8
Other Race Alone	7304
Two or More Races	648
Total Population	17545
Hispanic Origin	12102
Children Aged 6 and Younger	2419
Adults Aged 65 and Older	1408
Total Housing Units	5126

Demographics Statistics Source: 2000 US Census
*Calculated using an area-proportion spatial analysis technique.
Rounding may present small discrepancies with respect to total population.

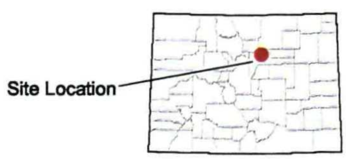
Study Area Demographics
Vasquez Boulevard/I-70 Site

Denver, Colorado

CERCLIS No. CO0002259588

VICINITY MAP

Base Map Source: 1995 TIGER/Line files, U.S. Census



Denver County, Colorado

ATSDR SAAGIS

MAM 10122001

Figure 3

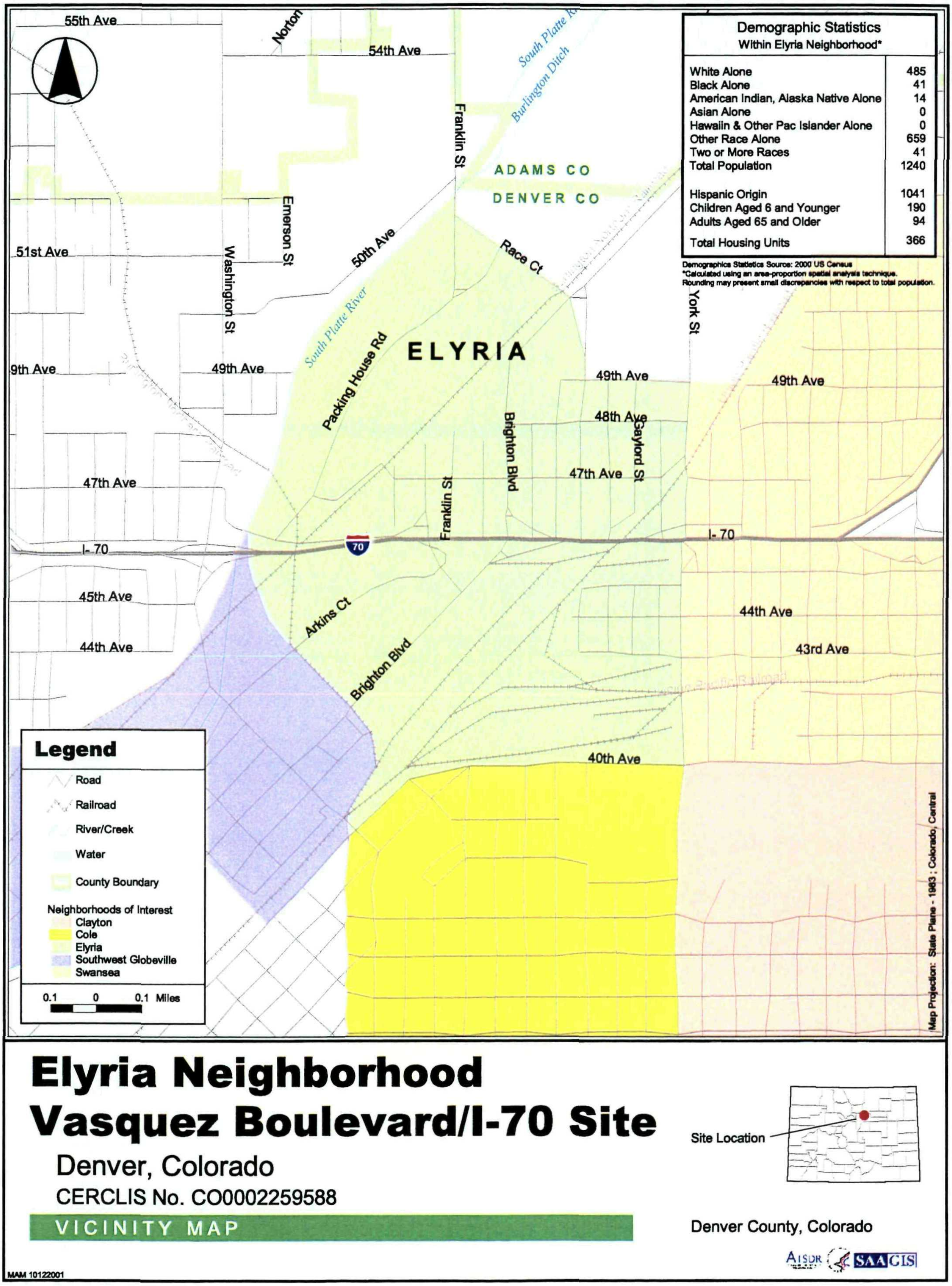
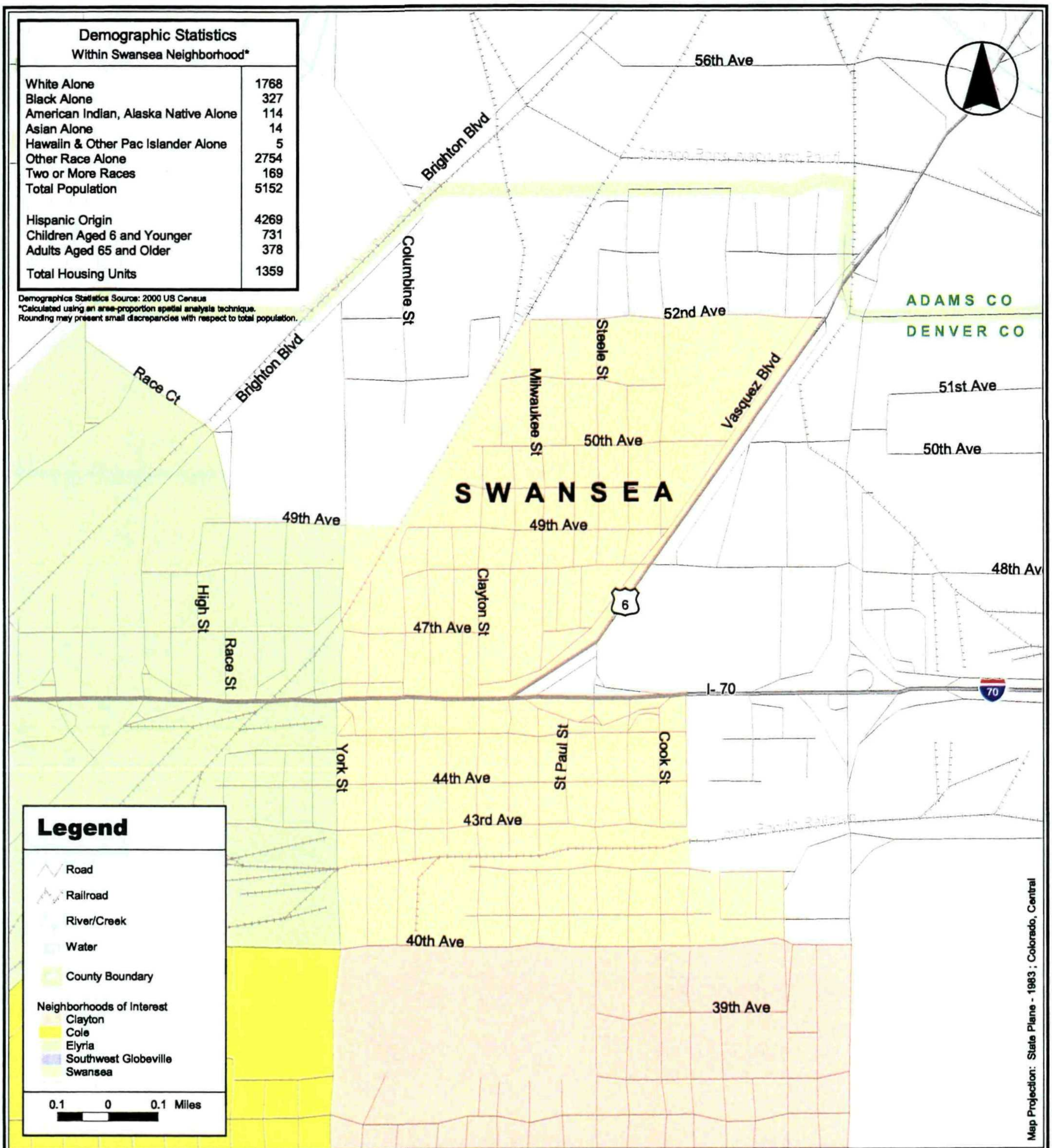

Demographic Statistics
Within Elyria Neighborhood*
White Alone 485
Black Alone 41
American Indian, Alaska Native Alone 14
Asian Alone 0
Hawaiin & Other Pac Islander Alone 0
Other Race Alone 659
Two or More Races 41
Total Population 1240
Hispanic Origin 1041
Children Aged 6 and Younger 190
Adults Aged 65 and Older 94
Total Housing Units 366
Demographics Statistics Source: 2000 US Census
*Calculated using an area-proportion spatial analysis technique.
Rounding may present small discrepancies with respect to total population.
55th Ave
Norton
54th Ave
South Platte River
Burlington Ditch
Franklin St
ADAMS CO
DENVER CO
Emerson St
Washington St
51st Ave
50th Ave
Race Ct
York St
South Platte River
Packing House Rd
ELYRIA
9th Ave
49th Ave
49th Ave
49th Ave
48th Ave
Gaylord St
Brighton Blvd
47th Ave
47th Ave
Franklin St
I-70
70
I-70
45th Ave
44th Ave
Arkins Ct
Brighton Blvd
44th Ave
43rd Ave
40th Ave
Legend
Road
Railroad
River/Creek
Water
County Boundary
Neighborhoods of Interest
Clayton
Cole
Elyria
Southwest Globeville
Swansea
0.1 0 0.1 Miles
Map Projection: State Plane - 1983 ; Colorado, Central
Elyria Neighborhood
Vasquez Boulevard/I-70 Site
Denver, Colorado
CERCLIS No. CO0002259588
VICINITY MAP
Site Location
Denver County, Colorado
MAM 10122001

Figure 4



Demographic Statistics Within Swansea Neighborhood*	
White Alone	1768
Black Alone	327
American Indian, Alaska Native Alone	114
Asian Alone	14
Hawaiin & Other Pac Islander Alone	5
Other Race Alone	2754
Two or More Races	169
Total Population	5152
Hispanic Origin	4269
Children Aged 6 and Younger	731
Adults Aged 65 and Older	378
Total Housing Units	1359

Demographics Statistics Source: 2000 US Census
*Calculated using an area-proportion spatial analysis technique.
Rounding may present small discrepancies with respect to total population.

Swansea Neighborhood
Vasquez Boulevard/I-70 Site

Denver, Colorado

CERCLIS No. CO0002259588

VICINITY MAP

Base Map Source: 1995 TIGER/Line files, U.S. Census

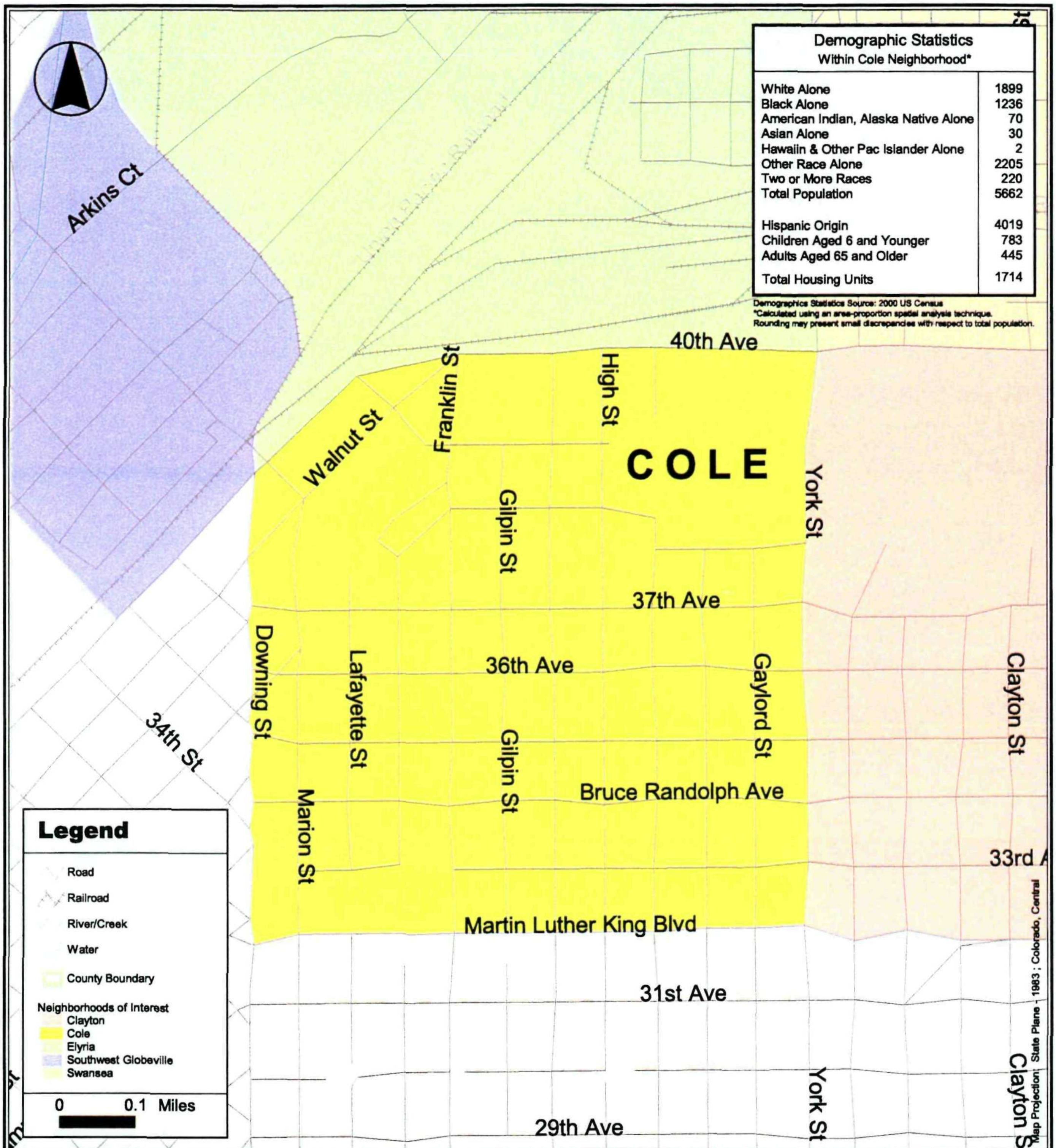
Site Location

Denver County, Colorado

ATSDR SAAGIS

MAM 10152001

Figure 5



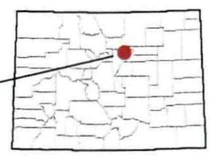
Demographic Statistics Within Cole Neighborhood*	
White Alone	1899
Black Alone	1236
American Indian, Alaska Native Alone	70
Asian Alone	30
Hawaiin & Other Pac Islander Alone	2
Other Race Alone	2205
Two or More Races	220
Total Population	5662
Hispanic Origin	4019
Children Aged 6 and Younger	783
Adults Aged 65 and Older	445
Total Housing Units	1714

Demographics Statistics Source: 2000 US Census
*Calculated using an area-proportion spatial analysis technique.
Rounding may present small discrepancies with respect to total population.

Cole Neighborhood
Vasquez Boulevard/I-70 Site

Denver, Colorado

CERCLIS No. CO0002259588



VICINITY MAP

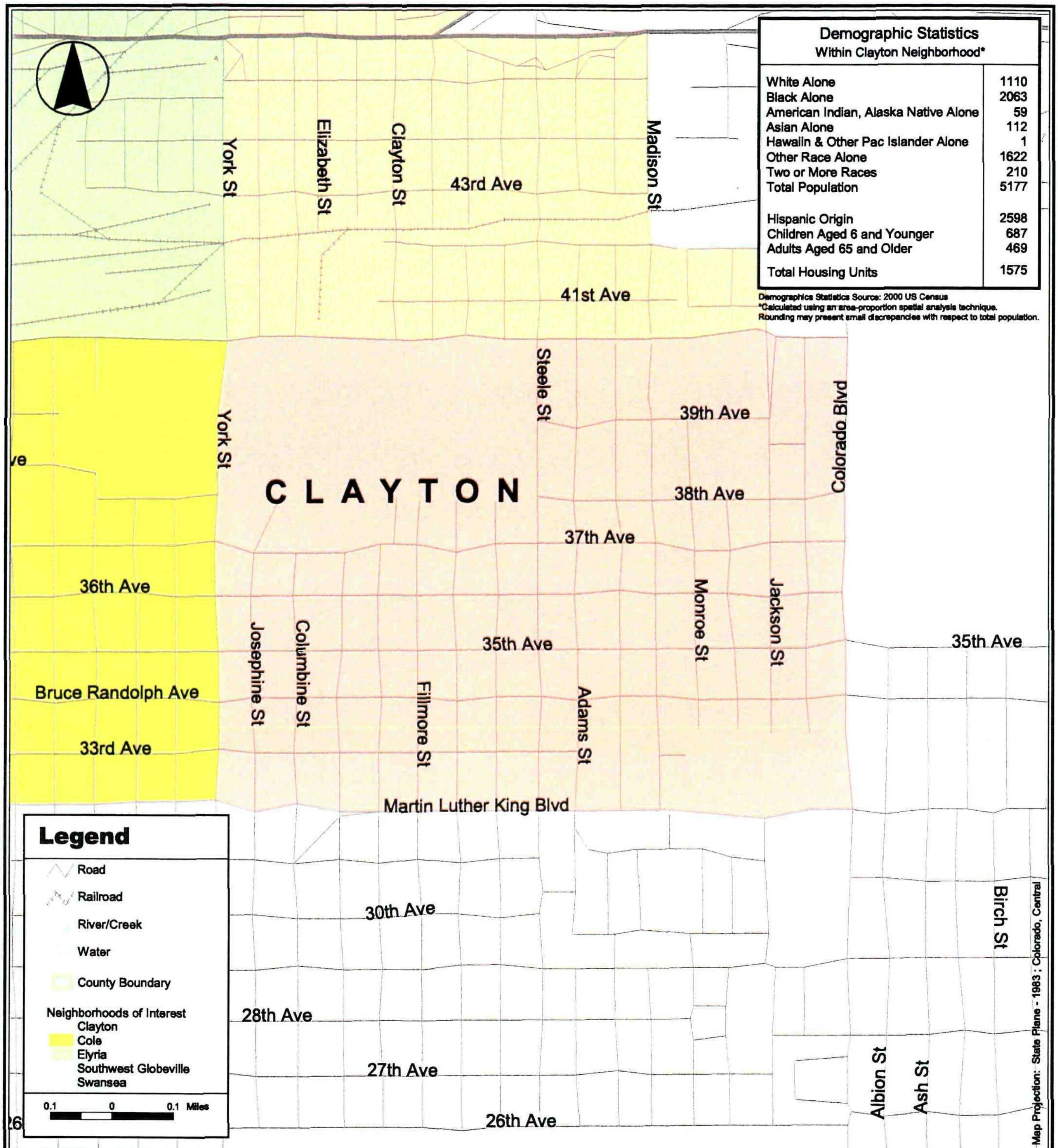
Base Map Source: 1995 TIGER/Line files, U.S. Census

Denver County, Colorado

ATSDR SAAGIS

MAM 10152001

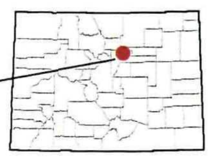
Figure 6



Clayton Neighborhood
Vasquez Boulevard/I-70 Site

Denver, Colorado

CERCLIS No. CO0002259588



VICINITY MAP

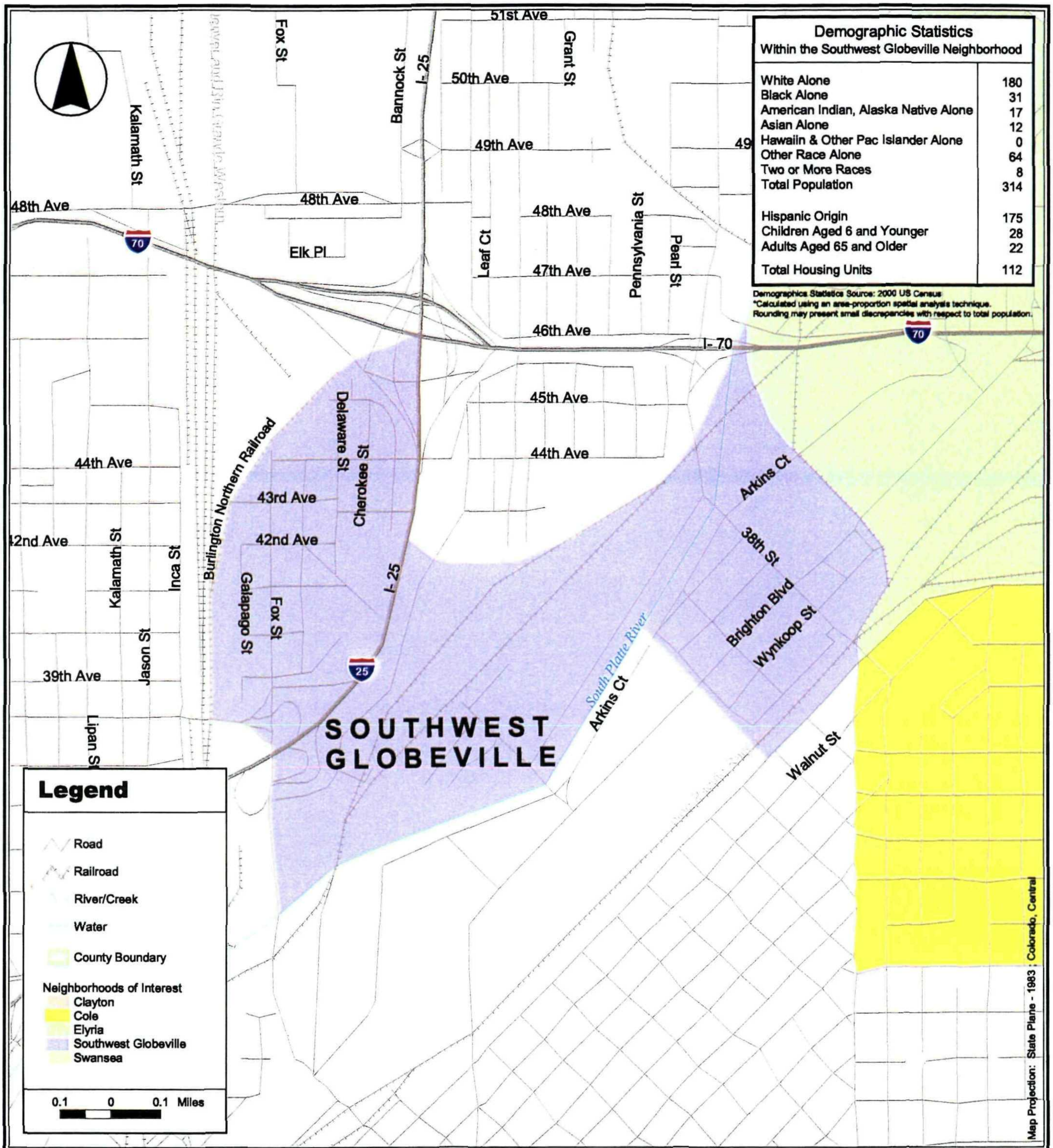
Base Map Source: 1995 TIGER/Line files, U.S. Census

Denver County, Colorado

ATSDR SAAGIS

MAM 10152001

Figure 7



Demographic Statistics
Within the Southwest Globeville Neighborhood

White Alone	180
Black Alone	31
American Indian, Alaska Native Alone	17
Asian Alone	12
Hawaiin & Other Pac Islander Alone	0
Other Race Alone	64
Two or More Races	8
Total Population	314
Hispanic Origin	175
Children Aged 6 and Younger	28
Adults Aged 65 and Older	22
Total Housing Units	112

Demographics Statistics Source: 2000 US Census
*Calculated using an area-proportion spatial analysis technique.
Rounding may present small discrepancies with respect to total population.

Southwest Globeville Neighborhood
Vasquez Boulevard/I-70 Site

Denver, Colorado

CERCLIS No. CO0002259588

VICINITY MAP

Base Map Source: 1995 TIGER/Line files, U.S. Census

Denver County, Colorado

ATSDR SAAGIS

MAM 10122001

Figure 8

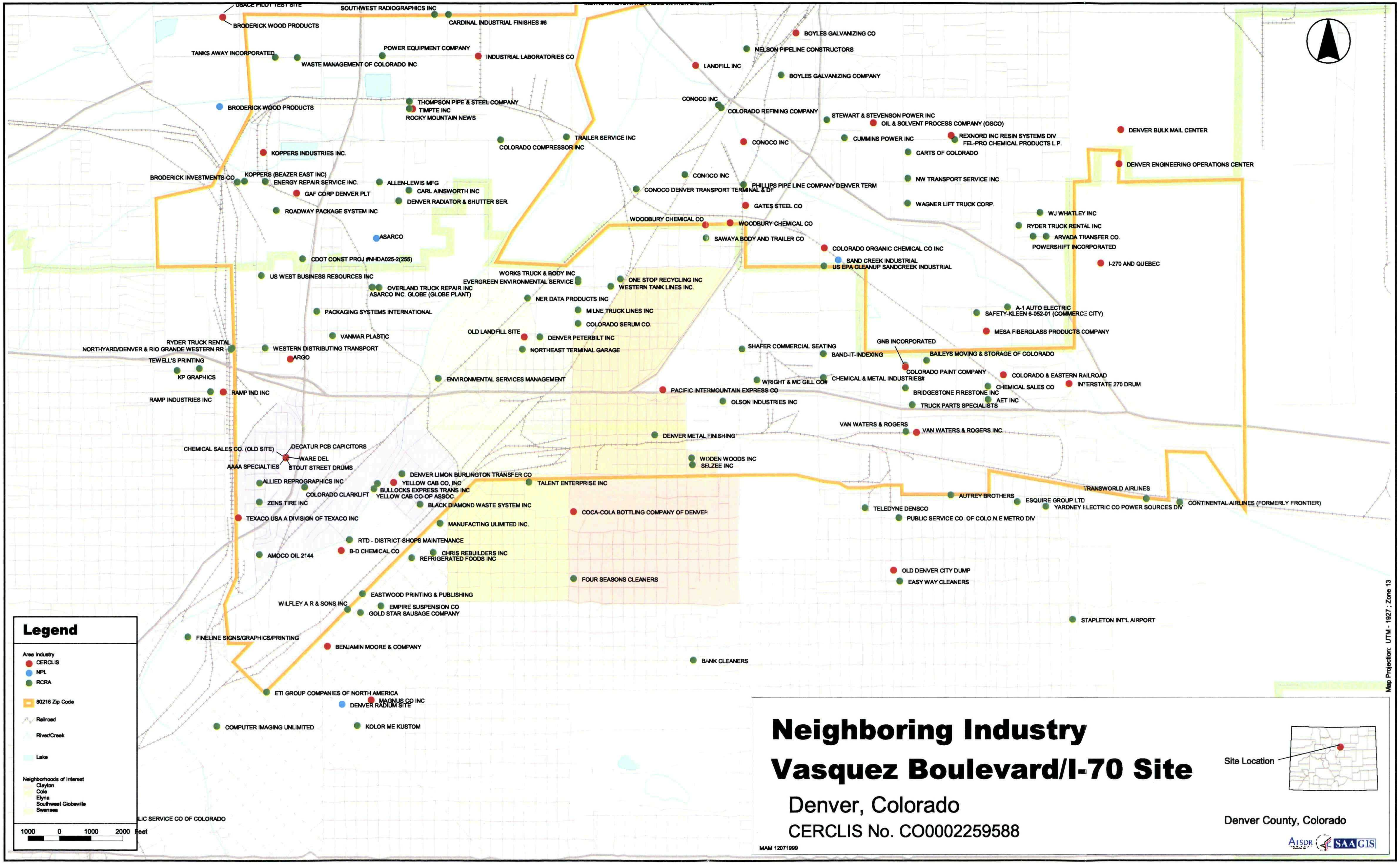

Neighboring Industry
Vasquez Boulevard/I-70 Site
Denver, Colorado
CERCLIS No. CO0002259588
Site Location
Denver County, Colorado
MAM 12071999
Map Projection: UTM - 1927 ; Zone 13
Legend
Area Industry
CERCLIS
NPL
RCRA
80216 Zip Code
Railroad
River/Creek
Lake
Neighborhoods of Interest
Clayton
Cole
Elyria
Southwest Globeville
Swansea
1000 0 1000 2000 Feet
USACE PILOT TEST SITE
SOUTHWEST RADIOGRAPHICS INC
CARDINAL INDUSTRIAL FINISHES #6
BRODERICK WOOD PRODUCTS
TANKS AWAY INCORPORATED
POWER EQUIPMENT COMPANY
WASTE MANAGEMENT OF COLORADO INC
INDUSTRIAL LABORATORIES CO
THOMPSON PIPE & STEEL COMPANY
TIMPTE INC
ROCKY MOUNTAIN NEWS
TRAILER SERVICE INC
COLORADO COMPRESSOR INC
KOPPERS INDUSTRIES INC.
BRODERICK INVESTMENTS CO
KOPPERS (BEAZER EAST INC)
ENERGY REPAIR SERVICE INC.
ALLEN-LEWIS MFG
CARL AINSWORTH INC
GAF CORP DENVER PLT
DENVER RADIATOR & SHUTTER SER.
ROADWAY PACKAGE SYSTEM INC
ASARCO
CDOT CONST PROJ #NHDA025-2(255)
US WEST BUSINESS RESOURCES INC
OVERLAND TRUCK REPAIR INC
ASARCO INC. GLOBE (GLOBE PLANT)
EVERGREEN ENVIRONMENTAL SERVICE
WORKS TRUCK & BODY INC
PACKAGING SYSTEMS INTERNATIONAL
VANMAR PLASTIC
RYDER TRUCK RENTAL
NORTHYARD/DENVER & RIO GRANDE WESTERN RR
WESTERN DISTRIBUTING TRANSPORT
TEWELL'S PRINTING
ARGO
KP GRAPHICS
RAMP IND INC
RAMP INDUSTRIES INC
ENVIRONMENTAL SERVICES MANAGEMENT
CHEMICAL SALES CO (OLD SITE)
DECATUR PCB CAPICITORS
WARE DEL
AAAA SPECIALTIES
STOUT STREET DRUMS
ALLIED REPROGRAPHICS INC
DENVER LIMON BURLINGTON TRANSFER CO
YELLOW CAB CO, INC
BULLOCKS EXPRESS TRANS INC
YELLOW CAB CO-OP ASSOC
COLORADO CLARKLIFT
ZENS TIRE INC
BLACK DIAMOND WASTE SYSTEM INC
TEXACO USA A DIVISION OF TEXACO INC
MANUFACTING ULIMITED INC.
RTD - DISTRICT SHOPS MAINTENANCE
B-D CHEMICAL CO
CHRIS REBUILDERS INC
REFRIGERATED FOODS INC
AMOCO OIL 2144
EASTWOOD PRINTING & PUBLISHING
WILFLEY A R & SONS INC
EMPIRE SUSPENSION CO
GOLD STAR SAUSAGE COMPANY
FINELINE SIGNS/GRAPHICS/PRINTING
BENJAMIN MOORE & COMPANY
ETI GROUP COMPANIES OF NORTH AMERICA
MAGNUS CO INC
DENVER RADIUM SITE
COMPUTER IMAGING UNLIMITED
KOLOR ME KUSTOM
LIC SERVICE CO OF COLORADO
BOYLES GALVANIZING CO
NELSON PIPELINE CONSTRUCTORS
LANDFILL INC
BOYLES GALVANIZING COMPANY
CONOCO INC
COLORADO REFINING COMPANY
STEWART & STEVENSON POWER INC
OIL & SOLVENT PROCESS COMPANY (OSCO)
CUMMINS POWER INC
REXNORD INC RESIN SYSTEMS DIV
FEL-PRO CHEMICAL PRODUCTS L.P.
CARTS OF COLORADO
DENVER BULK MAIL CENTER
DENVER ENGINEERING OPERATIONS CENTER
CONOCO INC
CONOCO DENVER TRANSPORT TERMINAL & DF
PHILLIPS PIPE LINE COMPANY DENVER TERM
NW TRANSPORT SERVICE INC
GATES STEEL CO
WAGNER LIFT TRUCK CORP.
WOODBURY CHEMICAL CO
WOODBURY CHEMICAL CO
SAWAYA BODY AND TRAILER CO
WJ WHATLEY INC
RYDER TRUCK RENTAL INC
ARVADA TRANSFER CO.
POWERSHIFT INCORPORATED
COLORADO ORGANIC CHEMICAL CO INC
SAND CREEK INDUSTRIAL
US EPA CLEANUP SANDCREEK INDUSTRIAL
I-270 AND QUEBEC
ONE STOP RECYCLING INC
WESTERN TANK LINES INC.
NER DATA PRODUCTS INC
MILNE TRUCK LINES INC
COLORADO SERUM CO.
OLD LANDFILL SITE
DENVER PETERBILT INC
NORTHEAST TERMINAL GARAGE
A-1 AUTO ELECTRIC
SAFETY-KLEEN 6-052-01 (COMMERCE CITY)
MESA FIBERGLASS PRODUCTS COMPANY
GNB INCORPORATED
SHAFER COMMERCIAL SEATING
BAND-IT-INDEXING
BAILEYS MOVING & STORAGE OF COLORADO
COLORADO PAINT COMPANY
COLORADO & EASTERN RAILROAD
WRIGHT & MC GILL CO
CHEMICAL & METAL INDUSTRIES
INTERSTATE 270 DRUM
PACIFIC INTERMOUNTAIN EXPRESS CO
BRIDGESTONE FIRESTONE INC
CHEMICAL SALES CO
OLSON INDUSTRIES INC
AET INC
TRUCK PARTS SPECIALISTS
VAN WATERS & ROGERS
VAN WATERS & ROGERS INC.
DENVER METAL FINISHING
WOODEN WOODS INC
SELZEE INC
TALENT ENTERPRISE INC
TRANSWORLD AIRLINES
AUTREY BROTHERS
ESQUIRE GROUP LTD
YARDNEY ELECTRIC CO POWER SOURCES DIV
CONTINENTAL AIRLINES (FORMERLY FRONTIER)
TELEDYNE DENSCO
PUBLIC SERVICE CO. OF COLO.N.E METRO DIV
COCA-COLA BOTTLING COMPANY OF DENVER
FOUR SEASONS CLEANERS
OLD DENVER CITY DUMP
EASY WAY CLEANERS
STAPLETON INT'L AIRPORT
BANK CLEANERS

Figure 9

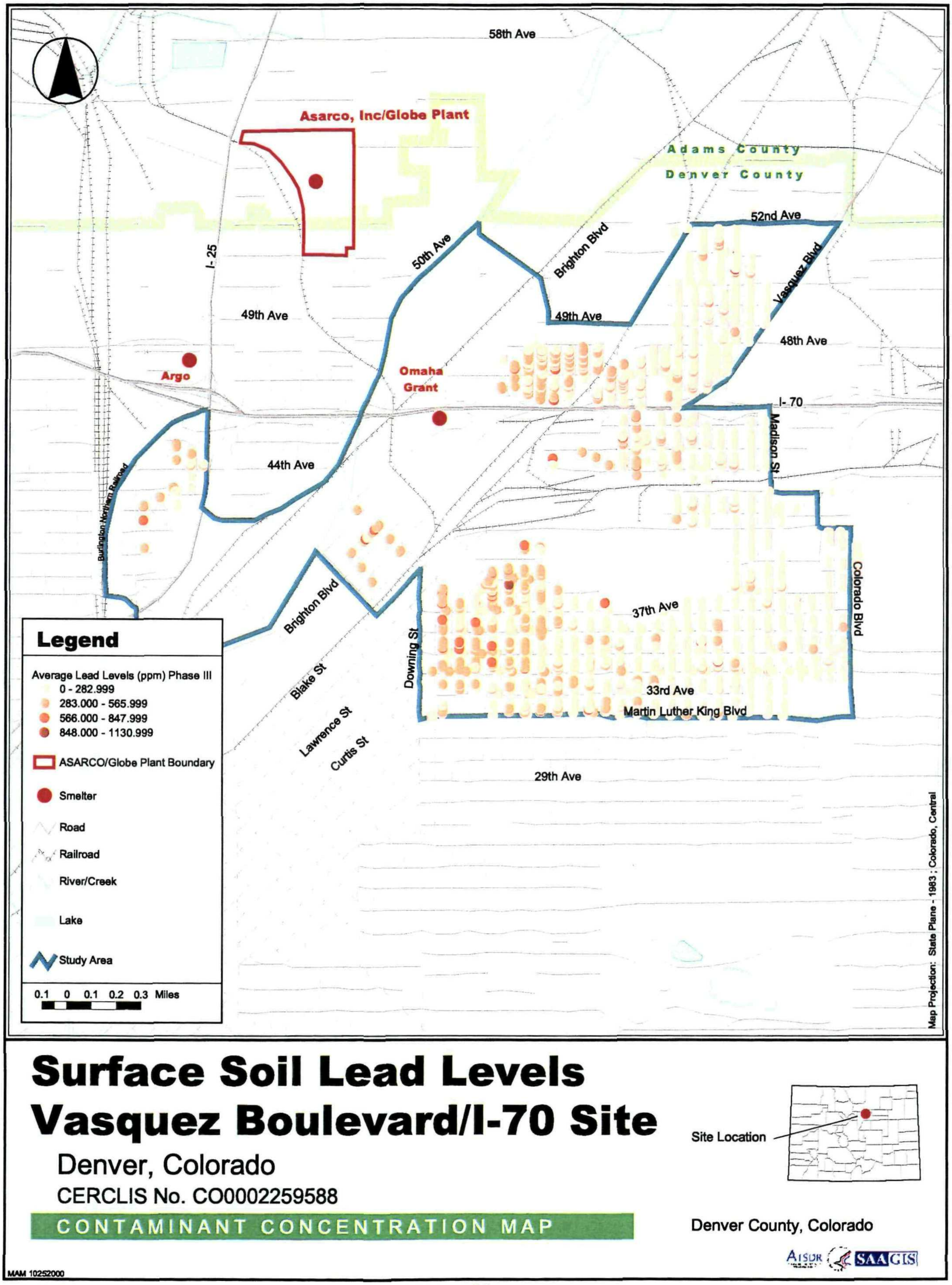
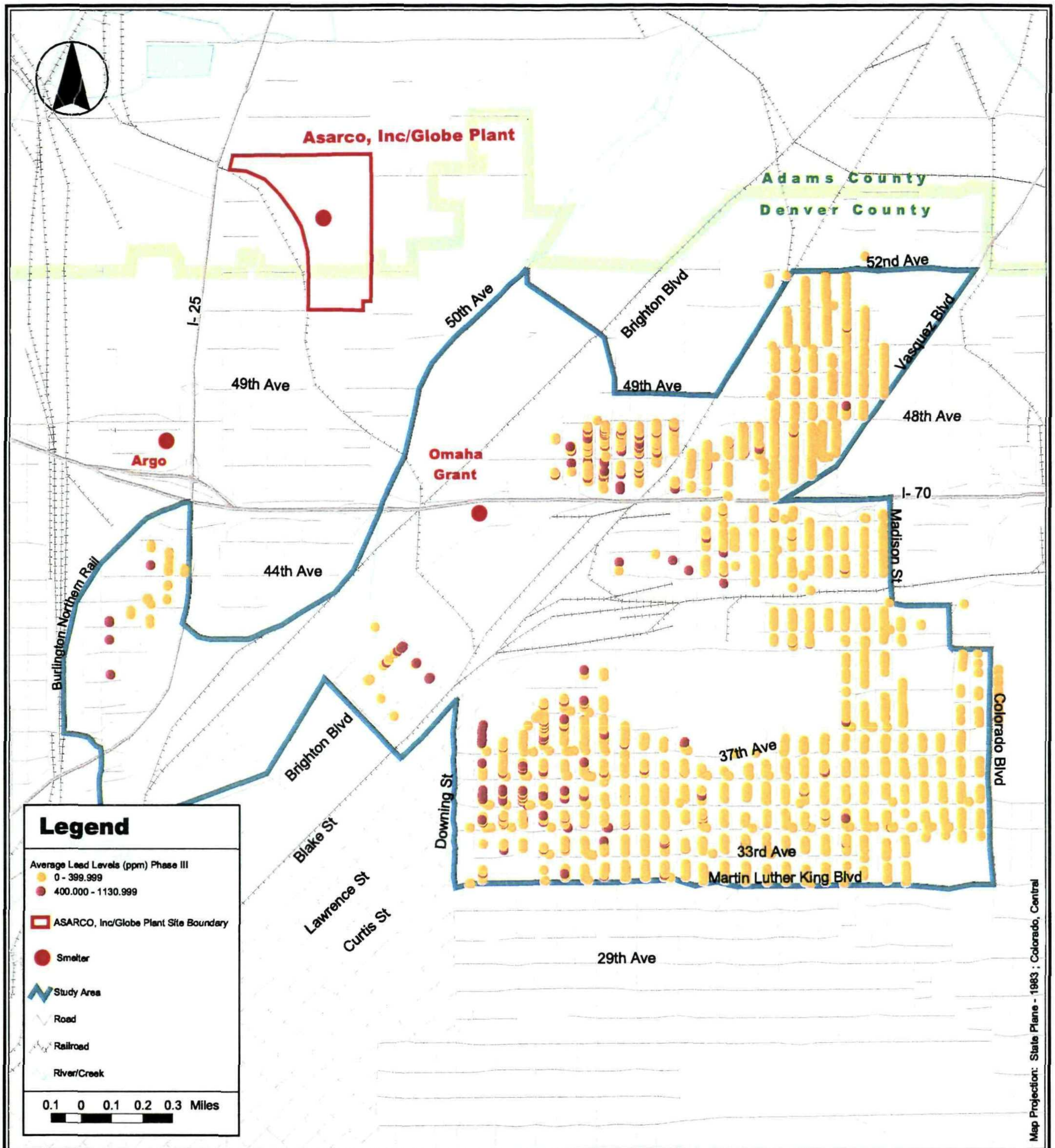

58th Ave
Asarco, Inc/Globe Plant
Adams County
Denver County
52nd Ave
Vasquez Blvd
Brighton Blvd
50th Ave
I-25
49th Ave
49th Ave
48th Ave
Argo
Omaha Grant
I-70
Madison St
44th Ave
Burlington Northern Railroad
Brighton Blvd
Colorado Blvd
37th Ave
Downing St
Blake St
33rd Ave
Martin Luther King Blvd
Lawrence St
Curtis St
29th Ave
Legend
Average Lead Levels (ppm) Phase III
0 - 282.999
283.000 - 565.999
566.000 - 847.999
848.000 - 1130.999
ASARCO/Globe Plant Boundary
Smelter
Road
Railroad
River/Creek
Lake
Study Area
0.1 0 0.1 0.2 0.3 Miles
Map Projection: State Plane - 1983 ; Colorado, Central
Surface Soil Lead Levels
Vasquez Boulevard/I-70 Site
Denver, Colorado
CERCLIS No. CO0002259588
CONTAMINANT CONCENTRATION MAP
Site Location
Denver County, Colorado
ATSDR
SAAGIS
MAM 10252000

Figure 10



Surface Soil Lead Levels
Vasquez Boulevard/I-70 Site

Denver, Colorado

CERCLIS No. CO0002259588

CONTAMINANT CONCENTRATION MAP

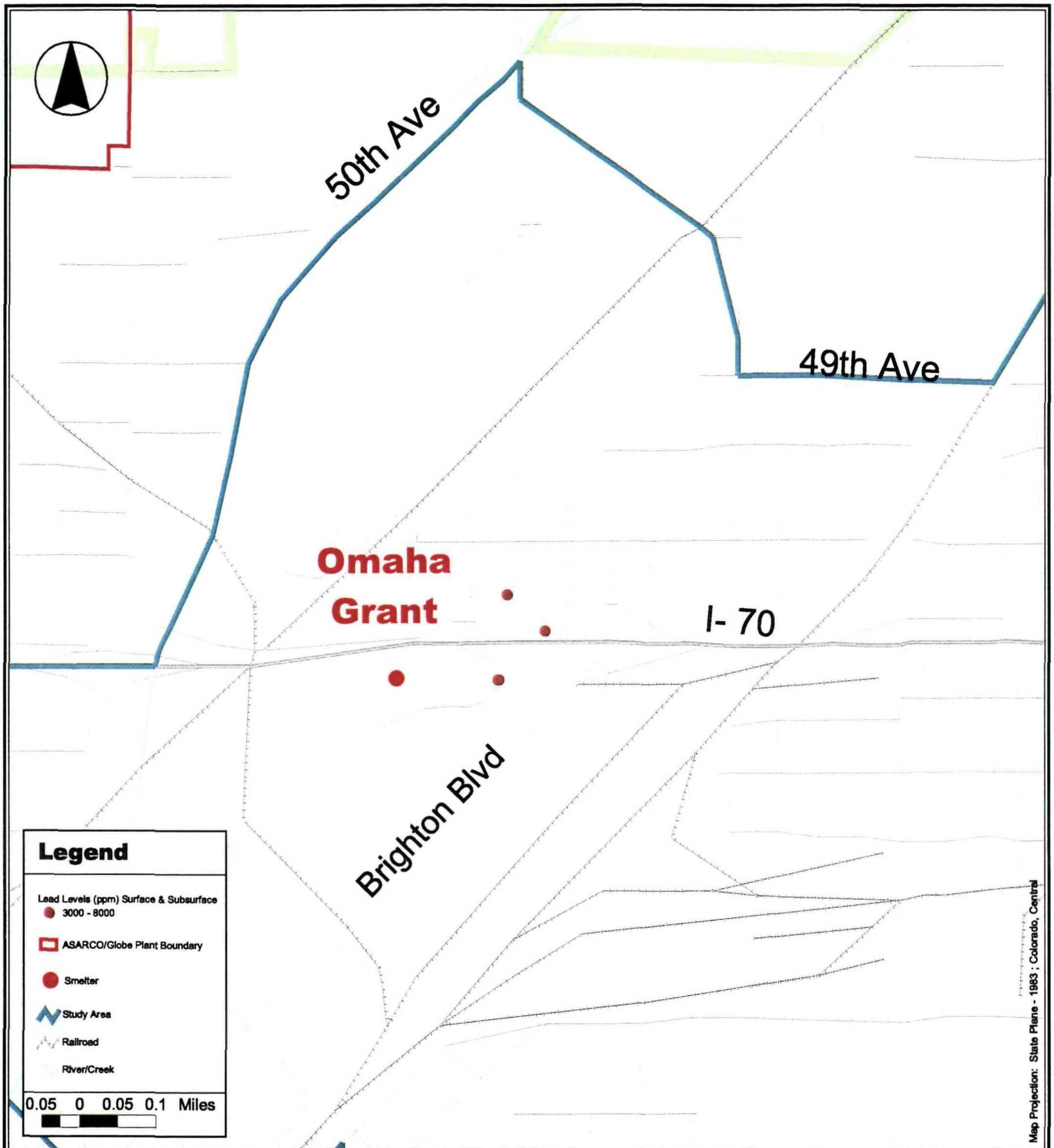
Site Location

Denver County, Colorado

ATSDR SAAGIS

MAM 08/02/2000

Figure 11



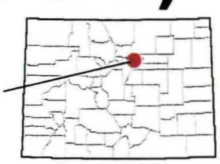
Highest Soil Lead Levels (Phase I & II)
Vasquez Boulevard/I-70 Site

Denver, Colorado

CERCLIS No. CO0002259588

CONTAMINANT CONCENTRATION MAP

Site Location

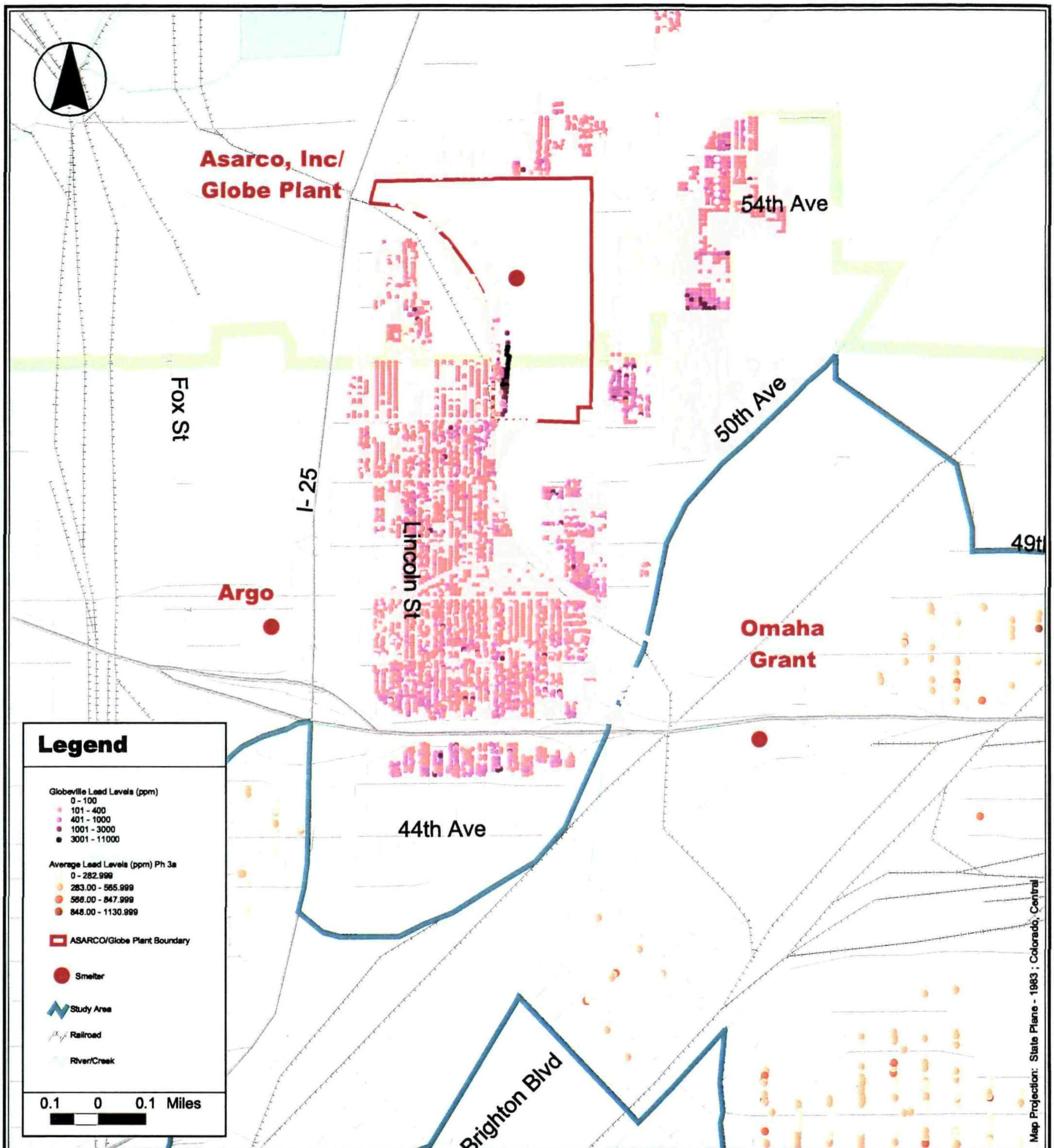


Denver County, Colorado

ATSDR SAAGIS

MAM 12201999

Figure 12



Surface Lead Levels - Globeville Vasquez Boulevard/I-70 Site

Denver, Colorado

CERCLIS No. CO0002259588

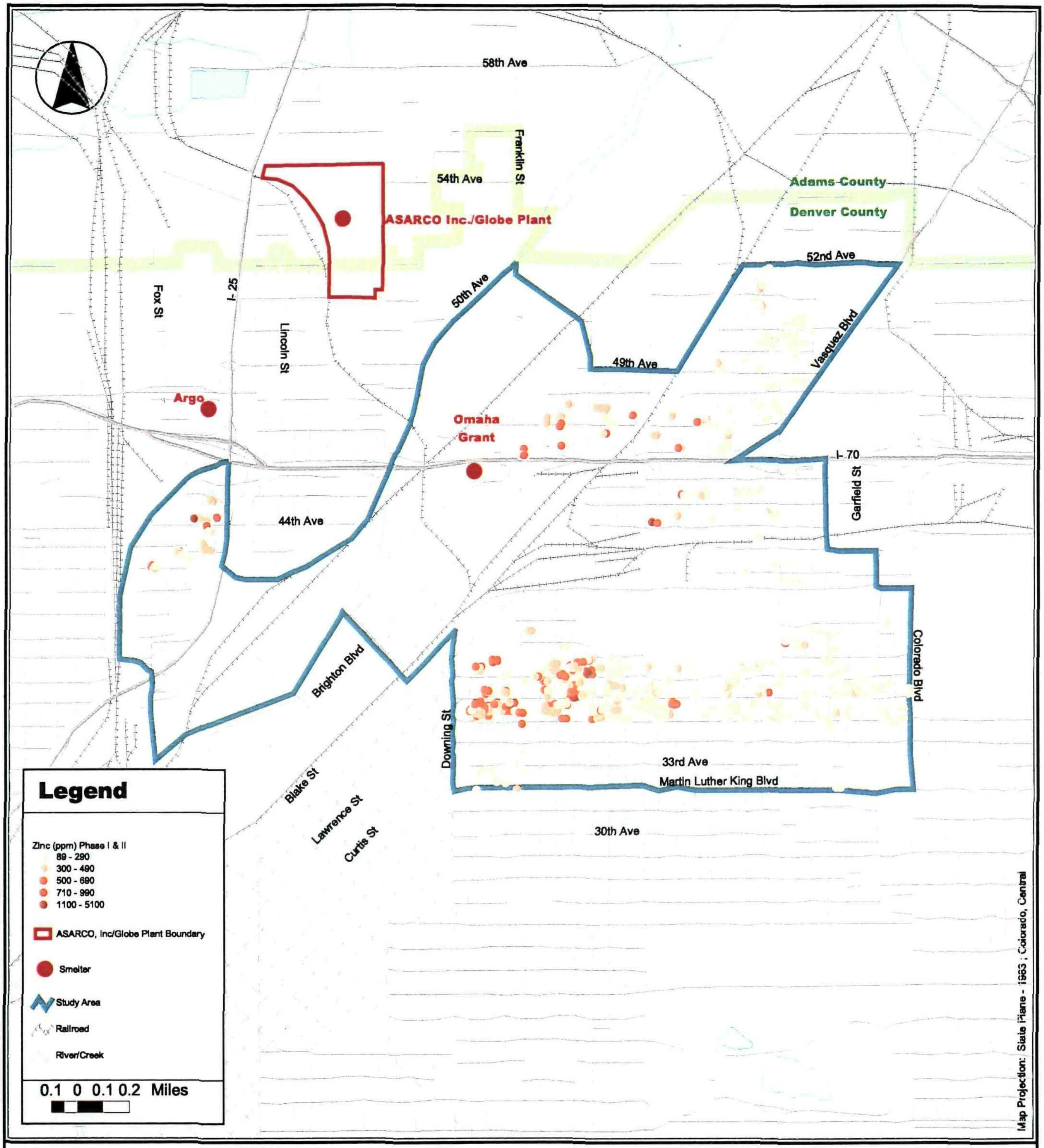
CONTAMINANT CONCENTRATION MAP

Denver County, Colorado

ATSDR SAAGIS

MAM 12201999

Figure 13

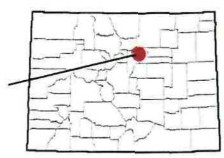


Surface Soil Zinc Levels Vasquez Boulevard/I-70 Site

Denver, Colorado

CERCLIS No. CO0002259588

CONTAMINANT CONCENTRATION MAP

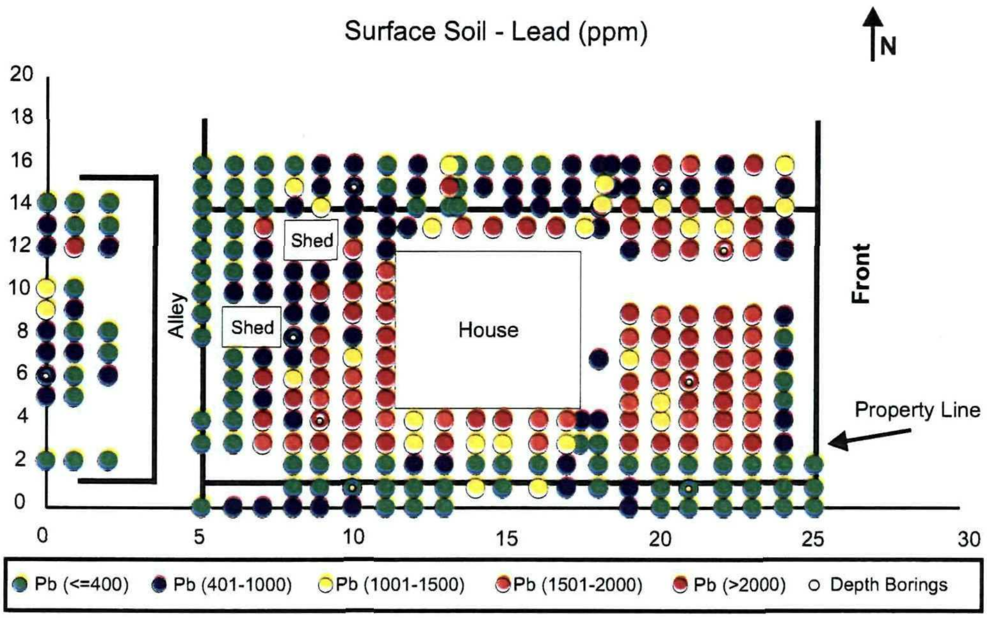


Denver County, Colorado

ATSDR SAAGIS

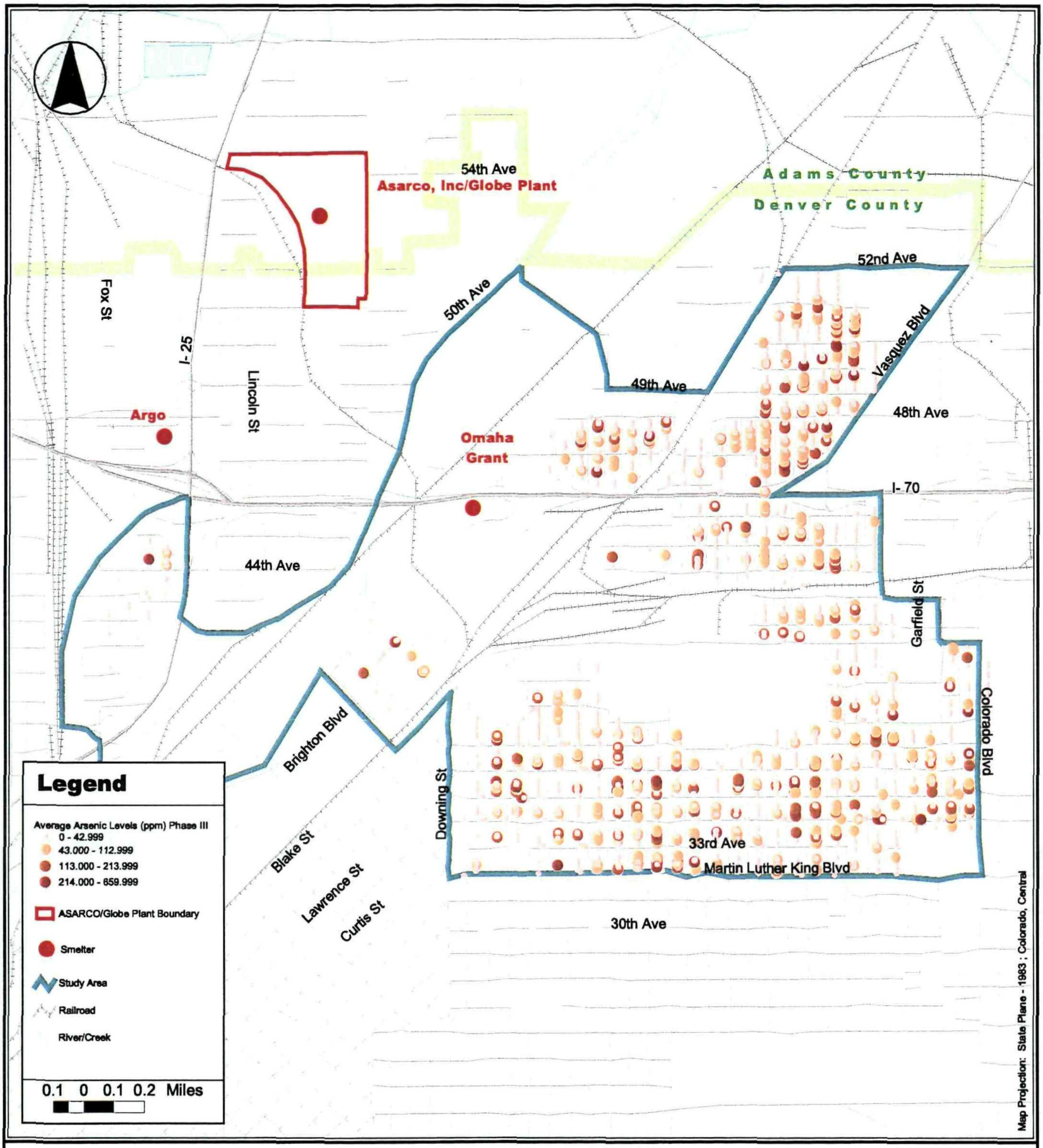
MAM 12161999

Figure 14



Scale is approximate

Figure 15

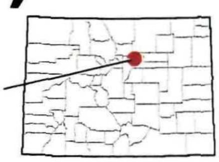


Surface Arsenic Levels (Phase III)
Vasquez Boulevard/I-70 Site

Denver, Colorado

CERCLIS No. CO0002259588

CONTAMINANT CONCENTRATION MAP

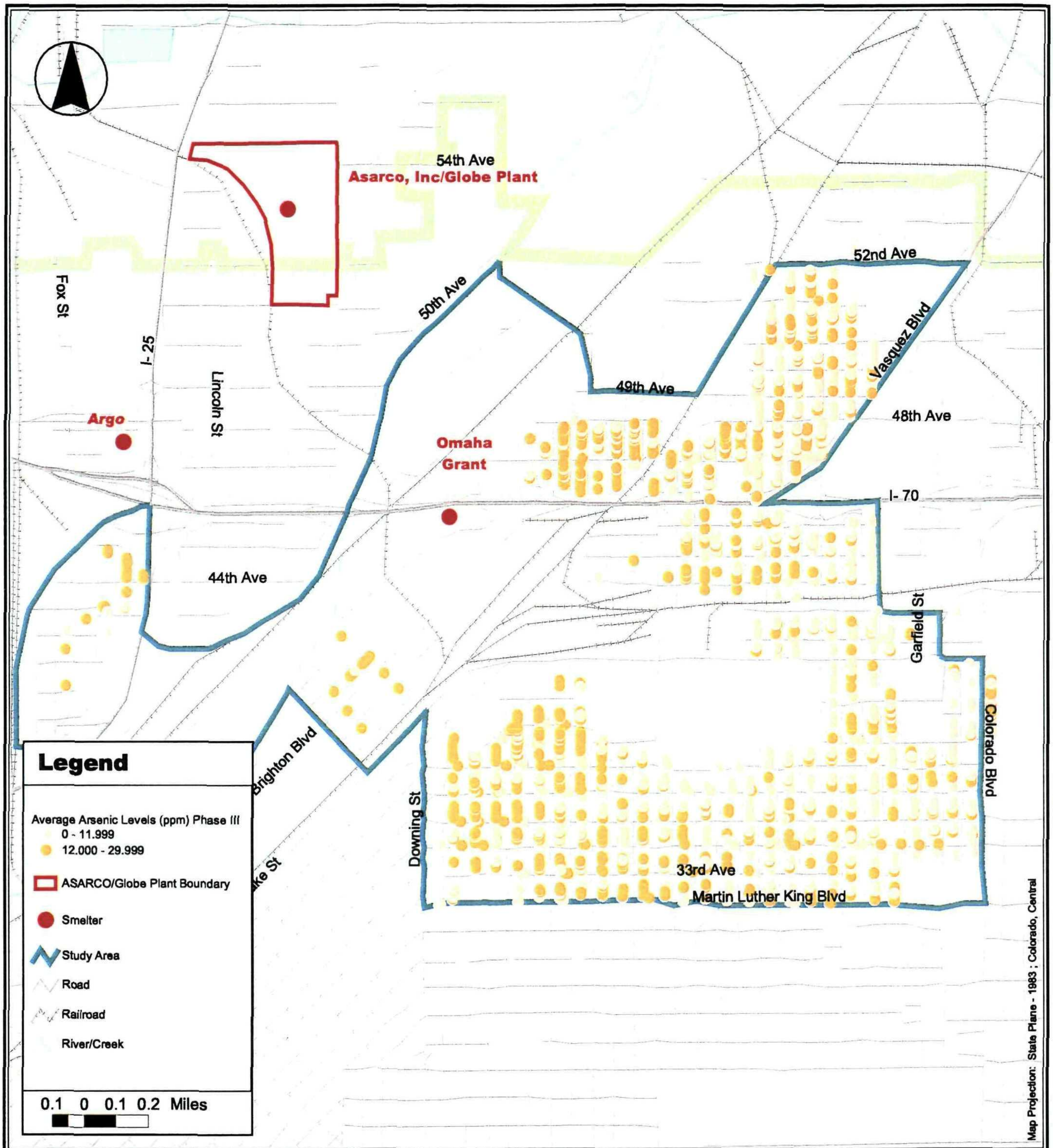


Denver County, Colorado

ATSDR SAAGIS

MAM 12201999

Figure 16



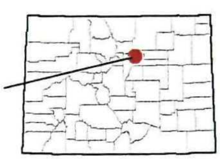
Surface Arsenic Levels
Vasquez Boulevard/I-70 Site

Denver, Colorado

CERCLIS No. CO0002259588

CONTAMINANT CONCENTRATION MAP

Site Location

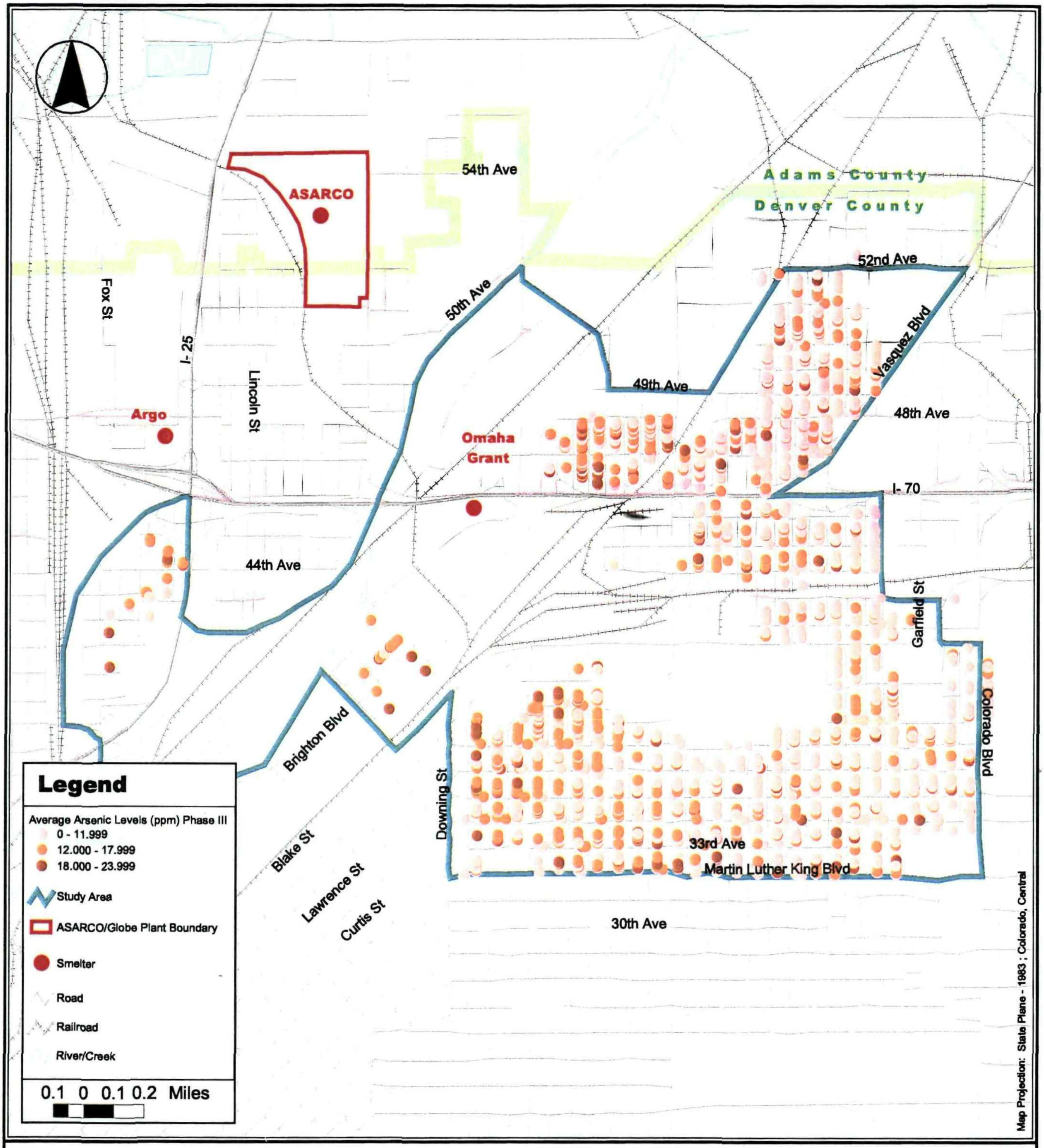


Denver County, Colorado

ATSDR SAAGIS

MAM 07192000

Figure 17



Surface Arsenic Levels
Vasquez Boulevard/I-70 Site

Denver, Colorado

CERCLIS No. CO0002259588

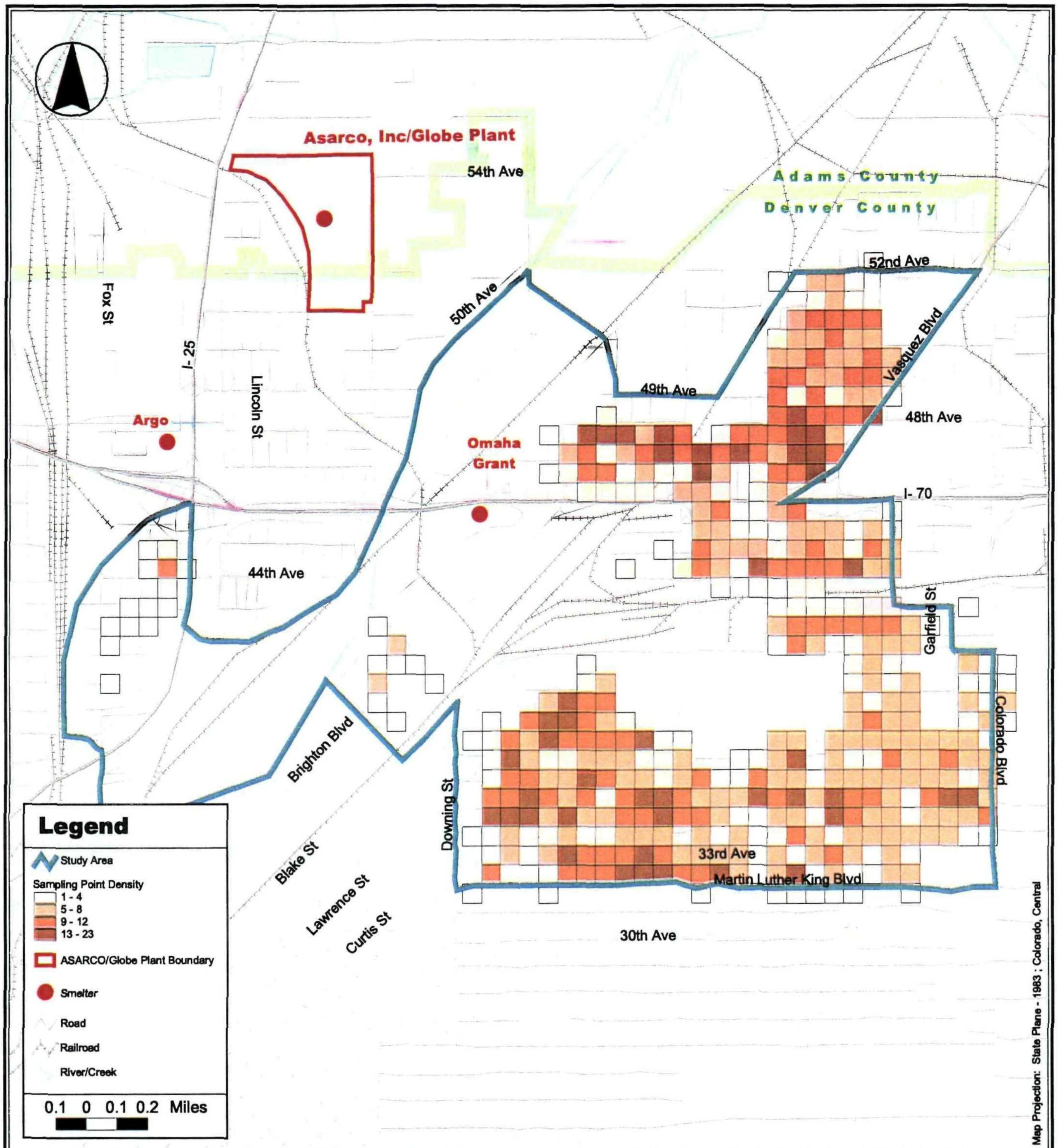
CONTAMINANT CONCENTRATION MAP

Denver County, Colorado

ATSDR SAAGIS

MAM 09072000

Figure 18



Sampling Point Density
Vasquez Boulevard/I-70 Site

Denver, Colorado

CERCLIS No. CO0002259588

SAMPLING ANALYSIS MAP

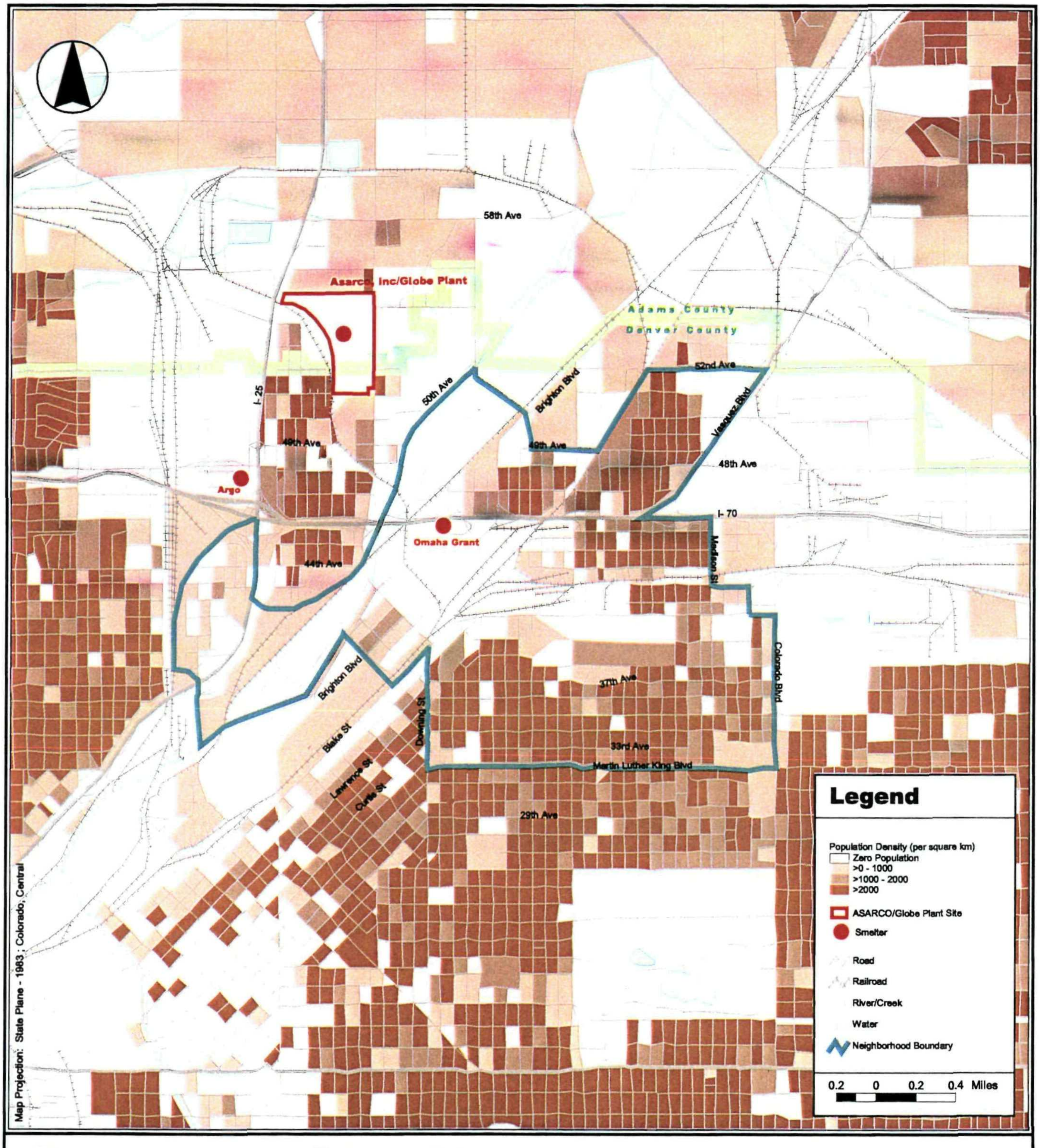
Site Location

Denver County, Colorado

ATSDR SAA GIS

MAM 10302000

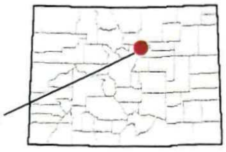
Figure 19



Population Density
Vasquez Boulevard/I-70 Site

Denver, Colorado

CERCLIS No. CO0002259588



DEMOGRAPHIC MAP

Base Map Source: 1995 TIGER/Line files, Population Density Source: 1990 U.S. Census

Denver County, Colorado

ATSDR SAA GIS

ALD 03191999

Figure 20

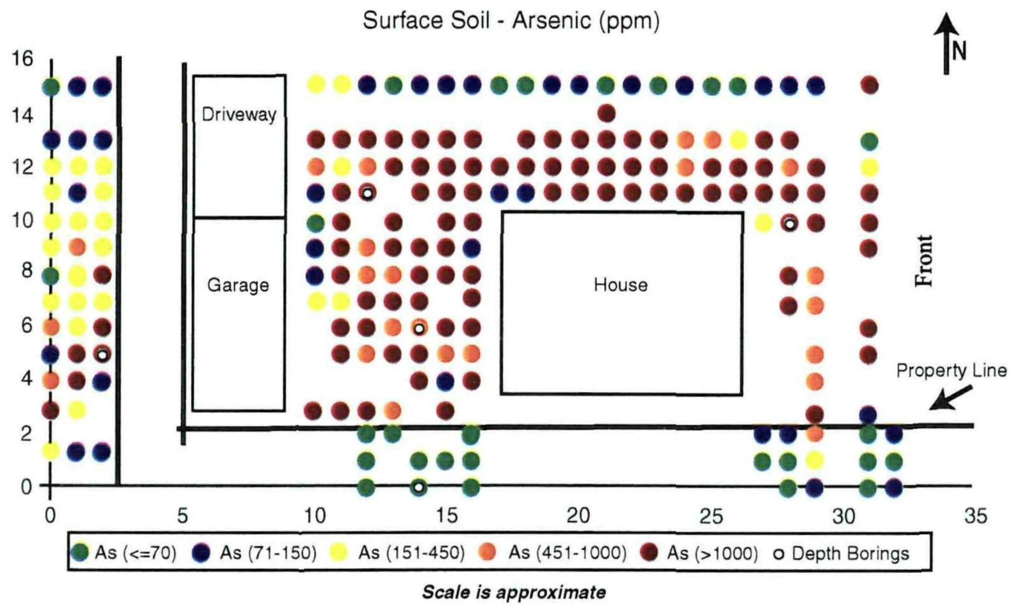
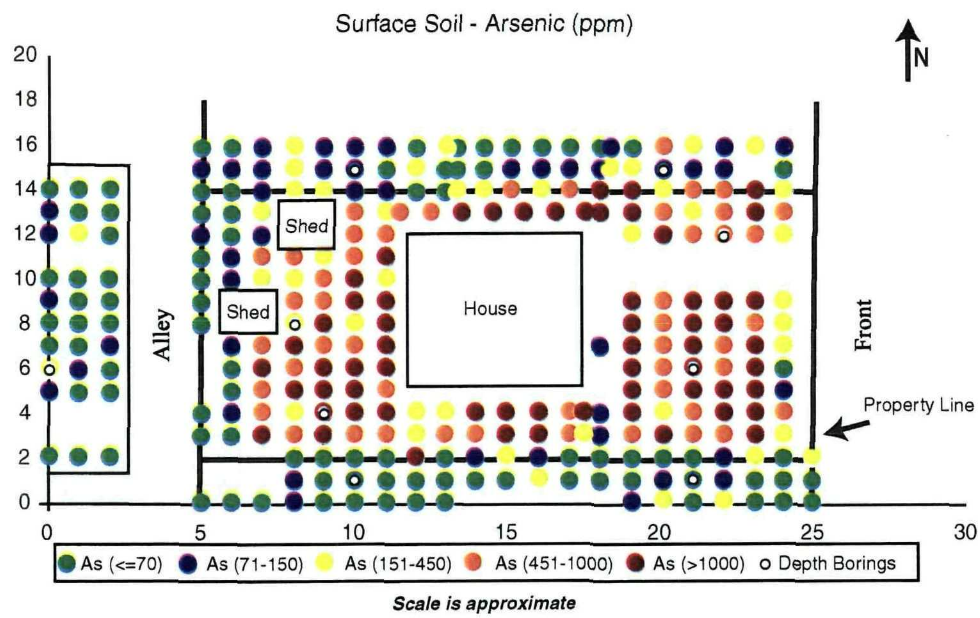
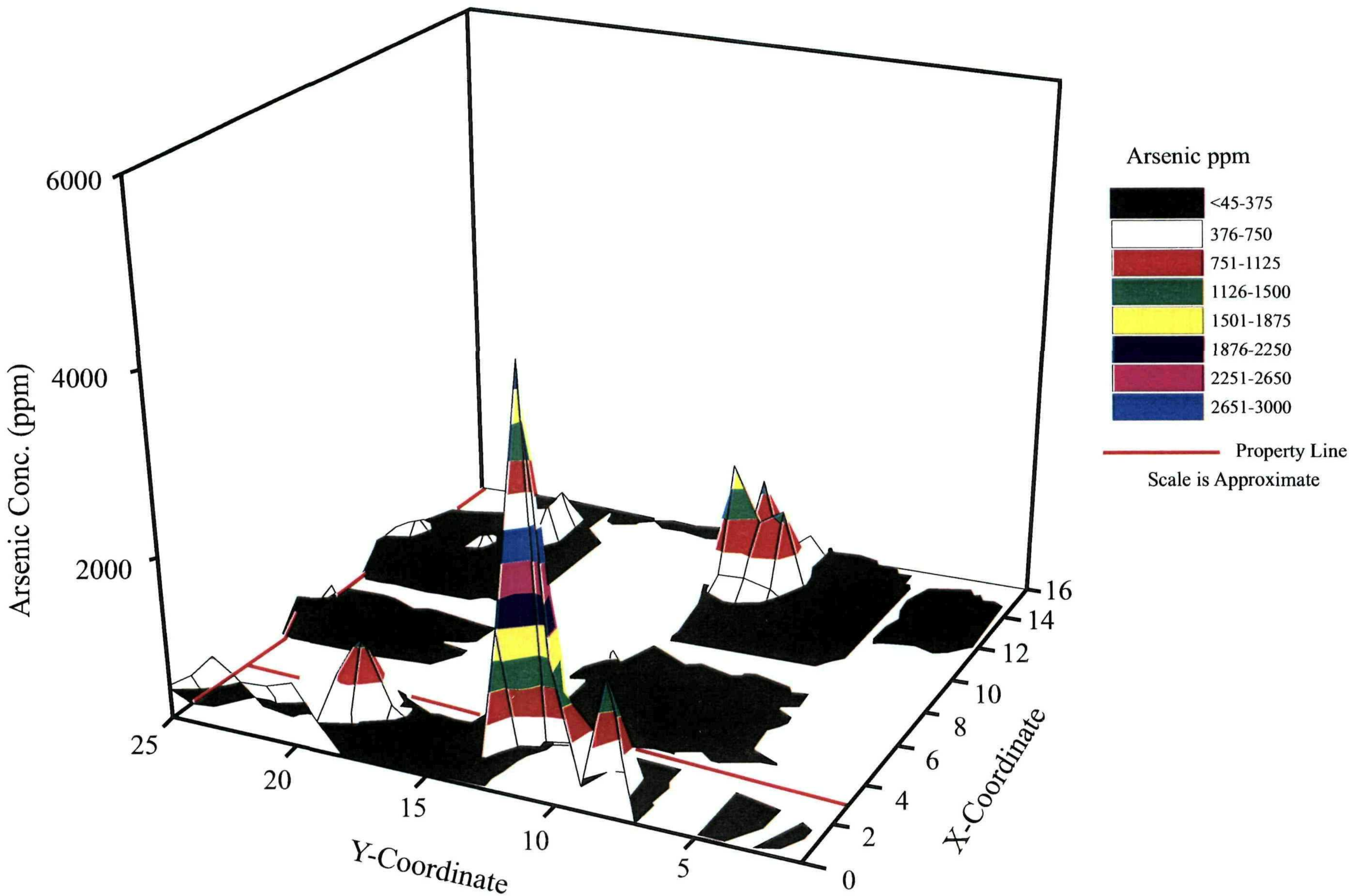

Surface Soil - Arsenic (ppm)
N
Driveway
Garage
House
Front
Property Line
16
14
12
10
8
6
4
2
0
0
5
10
15
20
25
30
35
As (<=70)
As (71-150)
As (151-450)
As (451-1000)
As (>1000)
Depth Borings
Scale is approximate

Figure 21



Surface Soil - Arsenic (ppm)
N
20
18
16
14
12
10
8
6
4
2
0
0
5
10
15
20
25
30
Shed
Shed
House
Alley
Front
Property Line
As (<=70)
As (71-150)
As (151-450)
As (451-1000)
As (>1000)
Depth Borings
Scale is approximate

Figure 22



Arsenic Conc. (ppm)
6000
4000
2000
25
20
15
10
5
Y-Coordinate
0
2
4
6
8
10
12
14
16
X-Coordinate
Arsenic ppm
<45-375
376-750
751-1125
1126-1500
1501-1875
1876-2250
2251-2650
2651-3000
Property Line
Scale is Approximate

Figure 23

Appendix C

Tables C-1 through C-5

Regional Geographic Initiative for Zip Code 80216

Table C-1
MOBILE SOURCE EMISSION INVENTORY FOR THE GLOBEVILLE AREA

POLLUTANT	TONS PER DAY
CARBON MONOXIDE	10840.00
NITROGEN OXIDES	2044
HYDROCARBONS	1387
PM_{10}	657
$PM_{2.5}$	292
SULFUR DIOXIDE	73
VEHICLE MILES TRAVELED	781545665

Table C-2
METALS EMISSIONS: 80216 by POLLUTANT AND COMPANY

SUBSTANCE	COMPANY	TONS PER YEAR
ARSENIC COMPOUNDS	PUBLIC SERVICE COMPANY	0.25
ANTIMONY COMPOUNDS	ASARCO INC GLOBE PLANT CHEMICAL& METAL IND INC	0.83 Total: 0.86 0.03
CADMIUM COMPOUNDS	ASARCO INC GLOBE PLANT	0.01
CHROMIUM COMPOUNDS	PUBLIC SERVICE COMPANY OWENS CORNING/DENVER ROOFING PLANT	0.13 Total: 0.16 0.03
MANGANESE COMPOUNDS	OWENS CORNING/DENVER ROOFING PLANT	0.03
NICKEL COMPOUNDS	PUBLIC SERVICE COMPANY	1.33
LEAD (TSP)	ASARCO INC GLOBE PLANT	0.50
LEAD COMPOUNDS	ASARCO INC GLOBE PLANT	0.01
SELENIUM	ASARCO INC GLOBE PLANT	0.06
TELLURIUM AND COMPOUNDS AS TE AND TE-PT	ASARCO INC GLOBE PLANT	0.13

Table C-3

TOTAL EMISSIONS: 80216 BY
TONS PER YEAR OF POLLUTANT

TONS PER YEAR	POLLUTANT
18332.00	SULFUR DIOXIDE
16822.37	NITROGEN DIOXIDE
875.28	VOLATILE ORGANIC COMPOUNDS (VOC)
714.86	CARBON MONOXIDE
659.18	SUSPENDED PARTICULATE (TSP)
349.25	PM10 TOTAL 0-10UM
151.64	TOTAL HAZARDOUS AIR POLLUTANTS
144.43	ORGANIC COMPOUNDS
33.17	TOLUENE AKA METHYBENZENE
12.25	AMMONIA
6.53	CHLOROFORM
2.31	CHLORIDE
1.33	NICKEL COMPOUNDS
0.95	ACIDS
0.86	ANTIMONY COMPOUNDS
0.50	LEAD (TSP)
0.36	HYDROGEN SULFIDE
0.25	ARSENIC COMPOUNDS
0.18	ISOPHORONE
0.16	CHROMIUM COMPOUNDS
0.13	TELLURIUM AND COMPOUNDS, AS TE
0.06	SELENIUM COMPOUNDS
0.03	MANGANESE COMPOUNDS
0.01	TRIETHYLAMINE
0.01	CADMIUM COMPOUNDS
0.01	LEAD COMPOUNDS
*******.**	HYDROFLUORIC ACID

Table C-4

TOP 10 VOLATILE ORGANIC COMPOUND (VOC) AND HAZARDOUS POLLUTANT (HP) EMITTERS

SIC	VOC/HC	INDUSTRY	# of businesses
2051	VOC	Bakeries	3
2499	VOC/HC	Wood Products	1
2599	VOC/HC	Furniture Manufacturer	1
2711	VOC	Newspaper (printing)	2
2752	VOC/HC	Commercial Print and Lithograph	13 (HC=9)
2851	VOC/HC	Paints/Painting Facilities	1
2952	VOC	Asphalt	1
3086	VOC	Plastic Foam Products	1
3317	HC	Steel Pipe	1
3441	HC	Fabricated Structural Material	2
3443	HC	Fabricated Plate Work	1
3479	HC	Metal Coating	2
4911	VOC/HC	Electric Utility	1
5541	VOC	Gasoline Stations	9

Table C-5

DIESEL FLEETS[25] BASED IN 80216
BY NUMBER OF TRUCKS

FLEET NAME	# OF TRUCKS
REGIONAL TRANSPORTATION DIST.	763
PENSKE TRUCK LEASING	604
CITY & COUNTY OF DENVER	411
DENVER PUBLIC SCHOOLS	315
RYDER TRUCK RENTAL-D.	281
HVH TRANSPORTATION, INC.	278
GLOBAL RENTAL	262
LEASE MIDWEST, INC.	225
ROLLINS LEASING CORP.-B	200
WASTE MANAGEMENT OF COLORADO	179
PEPSI-COLA BOTTLING CO.	144
U.S. WEST-DENVER	124
BRANNAN SAND & GRAVEL CO.	97
WESTERN DISTRIBUTING TRANS. C	75
ANHEUSER-BUSCH INC.	72
DON WARD & CO.	72
MAYFLOWER CONTRACT SERVICES	65
MILE-HI FROZEN FOODS CO.	58
N.P. TRANSPORTATION	57
READY MIXED CONCRETE CO.	56
SAFEWAY STORES, INC.	54
FULL SERVICE BEVERAGES	53
ZULANAS DISTRIBUTORS, INC.	46
ABF FREIGHT SYSTEMS, INC.	40
TRANS WESTERN EXPRESS, LTD.	40

[25] A fleet is considered to be nine or more trucks.

FLEET NAME	# OF TRUCKS
BULLOCKS EXPRESS	38
RYDER TRUCK RENTAL-L.	38
NEWS AND FILM SERVICE	33
NATIONAL BY-PRODUCTS, INC.	30
AMERICAN WAREHOUSE CO., INC.	26
FRANK C. KLEIN & CO., INC.	25
GIAMBROCCO FOOD SERVICE	24
WESTERN DELIVERY SERVICE	17
DPI DYKSTRA SALES, INC.	16
MOUNTAIN STATE TRUCK LEASING	15
BELLIO TRUCKING, INC.	14
IRON & METALS, INC.	13
ULTIMATE FROZEN FOODS, INC.	11
TOTAL	4871

Appendix D

Tables D-1, and D-2

Additional Demographics for the VBI70 Study Area

The demographic data presented in the main body of the report are taken from the 2000 census. In addiction to these data, ATSDR obtained and reviewed information prepared by Claritas, Inc.—a company that specializes in demographic data for specific geographic areas. The data provided by Claritas provide additional information relevant to this public health assessment, such as the age of houses and the average time people live in their homes.

The following list reviews important data trends derived from the demographic data provided by Claritas. Data summary tables are also included in this appendix to highlight notable demographic trends.

- *Housing stock by neighborhood.* Information on the housing stock is an important consideration for this public health assessment, especially because surface soils can be greatly disturbed (or even replaced with clean fill) during construction of new homes. Appendix D, Table D-1 presents data on the housing stock in the VBI70 study area; these data are based on estimated information for 1998.

  As Appendix D, Table D-1 shows, there are more than 5,000 housing units in the VBI70 study area, with the Clayton, Cole, and Swansea neighborhoods having the highest numbers of homes. Throughout the study area, nearly 90% of the housing units were believed to be occupied in 1998. About three-fourths of the housing units in this area have only one unit (i.e., they are single family homes), and multi-unit dwellings are most prevalent in the Cole neighborhood.

  According to the census data, more than 80% of the homes in the VBI70 study area were constructed before 1970, and most of these were built before 1950. Only 11% of the homes in the area were built in the last 15 years. New construction appears to be most prevalent in the Clayton and Cole neighborhoods. The Southwest Globeville neighborhood, on the other hand, has the highest fraction of older homes. Though some variations in the age of homes are apparent in different parts of the VBI70 study area, the variations are not striking and cannot (by themselves) explain the trends observed in the soil contamination.

- *Length of residence by neighborhood.* The length of time people live in the VBI70 study area is very relevant to this public health assessment: People who have lived in the area for many years are much more likely to have come into contact with contaminated soils than people who have lived in the area for only a couple of years. According to Appendix D, Table D-3, the median duration of residence for "block groups" in the VBI70 study area ranges from 6.8 years to 23.3 years. (Note, a block group is a small subset of a neighborhood; the census uses block groups to report population data for parts of cities.) This means that residents in some parts of the VBI70 study area tend to move to new locations every 7 years or so, but residents in other parts of the VBI70 study area tend to not move from their homes for more than 23 years.

For greater insight into duration of residence, the Claritas data was used to estimate how long people in the VBI70 study area live in their homes. These data are also shown in Appendix D, Table D-2 Averaged over the entire study area, 53% of the residents are believed to live in their current homes for 10 years or fewer, while 16% of the residents are believed to have lived in their current homes for more than 30 years. Therefore, about 16% of the residents have the potential for exposures greater than 30 years.

Comparing these data across the five neighborhoods, ATSDR found that the percentage of long-term residents does not vary considerably from one neighborhood to the next. In fact, the percentages of long-term residents (30 years or more) in Clayton, Cole, Elyria, and Swansea are almost identical, with slightly higher percentages for Southwest Globeville. Overall, though some neighborhood-specific trends in duration of residency are apparent, no single neighborhood has a strikingly different distribution for this parameter than others. In other words, no single neighborhood stands out as having residents that have lived considerably longer in their homes when compared to the other four neighborhoods.

Table D-1
Data on the Housing Stock in the Five Neighborhoods in the VBI70 Study Area
(Data Presented Are Estimates for the Year 1998)

Parameter	Data for the Area within the VBI70 Study Area	Neighborhood				
		Clayton	Cole	Elyria	Southwest Globeville	Swansea
Total Housing Units and Occupancy Data:						
Total Housing Units	5,145	1,665	1,770	391	298	1,020
Total Occupied Housing Units	4,516	1,509	1,441	348	268	949
Estimated Occupancy Rate	88%	91%	81%	89%	90%	93%
Distribution of Types of Housing Units:						
Single Unit Homes	3,847 (75%)	1,273 (76%)	1,142 (65%)	285 (73%)	248 (83%)	899 (88%)
Homes with 2–9 Units	978 (19%)	329 (20%)	448 (25%)	87 (22%)	31 (10%)	83 (8%)
Homes with 10 or More Units	235 (5%)	50 (3%)	160 (9%)	6 (2%)	13 (4%)	5 (<1%)
Mobile Homes and Other	84 (2%)	13 (1%)	20 (1%)	13 (3%)	6 (2%)	32 (3%)
Breakdown of Housing Stock by Year Homes Were Constructed:						
Homes Built in 1985 or Later	590 (11%)	288 (17%)	232 (13%)	30 (8%)	12 (4%)	27 (3%)
Homes Built in 1980–1984	97 (2%)	54 (3%)	27 (2%)	6 (2%)	9 (3%)	0 (0%)
Homes Built in 1970–1979	288 (6%)	32 (2%)	113 (6%)	61 (16%)	13 (4%)	69 (7%)
Homes Built in 1950–1969	983 (19%)	370 (22%)	173 (10%)	70 (18%)	31 (10%)	339 (33%)
Homes Built before 1950	3,187 (62%)	921 (55%)	1,225 (69%)	224 (57%)	232 (78%)	584 (57%)

Note: All data in the table are estimates of the 1998 population. These estimates were prepared for ATSDR by Claritas, Inc.

Table D-2
Data on Duration of Residence for the Five Neighborhoods in the VBI70 Study Area
(Data Presented Are Estimates for the Year 1998)

Parameter	Data for the Population Living within the VBI70 Study Area	Neighborhood				
		Clayton	Cole	Elyria	Southwest Globeville	Swansea
Data on Median Duration of Residency (see notes at the bottom of the table):						
Shortest median length of residence for a block group within the area listed	6.8	11.4	6.8	8.5	7.7	8.5
Longest median length of residence for a block group within the area listed	23.3	18.2	23.3	15.0	14.1	15.0
Data on Duration of Residency; Percent of Householders Who Moved into Their Housing Units. . .						
. . . 0 to 5 years ago	43%	39%	47%	57%	46%	37%
. . . 6 to 10 years ago	10%	7%	10%	10%	3%	17%
. . . 11 or more years ago	46%	53%	43%	33%	41%	46%
. . . 30 or more years ago	16%	14%	16%	15%	20%	16%

Notes: The five neighborhoods in the VBI70 study area are comprised of many "block groups" or regions the U.S. Census uses to characterize the population. For each block group in these neighborhoods, the census data reports the median duration of residency for all of the residents in the block group. The data in the table above presents the lowest and highest median duration of residency for all block groups in a given area. Therefore, one can conclude that the median duration of residency for the entire neighborhood is between the lowest and highest data points provided.

In the second presentation of data, note that the last category ("30 or more years ago") is actually a subset of the category before it ("11 or more years ago"). Because of this, the percentages listed do not add up to 100.

Appendix E

CDPHE's Fact Sheet on Gardening in the VBI70 Study Area

Colorado Department of Health and Environment
April 1999

Home Gardening

For the residents of Globeville (south of I-70), Swansea, Elyria, Cole and Clayton neighborhoods

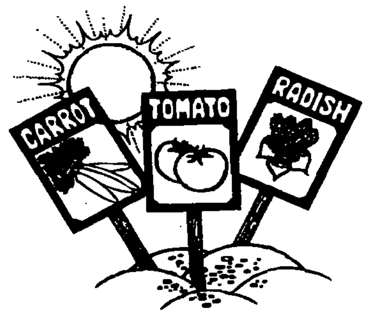
Several public health agencies are studying soil samples in your neighborhood to see if there are any metals present that might pose a health risk. More information will be available from these ongoing studies, and this information may need to be revised.

If you decide to garden this season, here is some general information about metals and gardening, and some steps that you can take to reduce the levels of metals that fruits and vegetables grown in your garden may take in if there are metals present in your garden soil.

Metals and gardening

- Garden soils tend to have less metal than the rest of the yard. This is because people have added commercial garden products or materials from outside the area like topsoil and compost to their garden soil.
- Fruits and vegetables from the garden usually have less metal than the soil they are grown in. This is because not all the metal is absorbed by the plants.
- The primary way plants take in metals is from the roots, along with the nutrients plants need for growth. A smaller amount of metals may get into the plant in small particles the plant "breathes" in through leaf openings. Metals may also be present in the dust or soil that collects on the outside of the plant.
- The ability of a plant to take up metals from soil and store them in their leaves and fruits varies from plant to plant.

What can I do to help protect my health?



Your garden soil

- **You can add things such as compost, topsoil and phosphate from commercial and other outside sources to your garden soil. These products are available at your local garden store, will enrich your soil, and will help reduce the amount of metals that can be taken up by plants in your garden.**

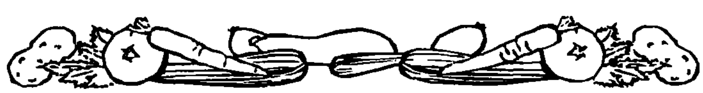
- After gardening be sure to wash up, especially your hands, clothes and shoes, to remove dust and soil and to avoid tracking soil into your home.

Your fruits and vegetables

- **You can eat some fruits and vegetables grown from your garden, and some from the grocery store. This will reduce the possibility of being exposed to metals which may be in your garden soil.**

- Wash and peel fruits and vegetables to reduce the amount of dust and dirt on the outside of fruits and vegetables.

You can call the Colorado Health and



following people at the Department of Public Environment for more

information

For information on garden studies/health effects:
Jane Mitchell
(303) 692-2644 or 1(800)886-7689
jane.mitchell@state.co.us

Nancy Strauss *(habla español)*
(303) 692-2785 or 1(800)886-7689
nancy.strauss@state.co.us

For information on metals in your soil:
Barbara O'Grady
(303) 692-3395 or 1(888)569-1831
barbara.ogrady@state.co.us

Marion Galant
(303) 692-3304 or 1(888)569-1831
marion.galant@state.co.us

For more information about metals in your soil or health effects, you may call the Agency for Toxic Substances and Disease Registry, Regional Representative Susan Muza at (303) 312-7011. For more information about gardening in general, you can call the Colorado State University Cooperative Extension Master Gardener at (303) 640-5278.

Prepared by Colorado Department of Public Health and Environment, 4300 Cherry Creek Drive South, Denver, CO 80246-1530. This fact sheet was supported in whole by funds from the Comprehensive Environmental Response, Compensation, and Liability Act trust fund through a cooperative agreement with the Agency for Toxic Substances and Disease Registry, Public Health Service, US Dept. of Health & Human Services.

Appendix F

ATSDR's Fact Sheet Evaluating Gardening in the VBI70 Study Area

Eating Vegetables from your Garden in Swansea, Elyria, Cole, Clayton, & South Globeville

Soil Sampling in your Neighborhood . . .

As you might know, soil from yards in the Vasquez Boulevard and Interstate 70 Superfund Site study area (VBI-70 area) is currently being tested to see if it contains elevated levels of metals such as arsenic and lead. The study area includes the communities of Swansea, Elyria, Cole, Clayton, and southwest Globeville (south of Interstate 70 and west of Interstate 25). As the sample results become available, several public health agencies are looking at them to see if the metals that are found could cause health problems.

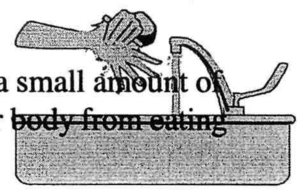
Eating Vegetables from your Garden . . .

The Agency for Toxic Substances and Disease Registry (ATSDR) along with the Colorado Department of Public Health and Environment (CDPHE) just finished an evaluation that looked at fruits and vegetables that are grown in yards where metals are found in the soil. Since arsenic is the metal that has been found most often at elevated levels in the yards that have been sampled so far, the study answered these questions about arsenic:

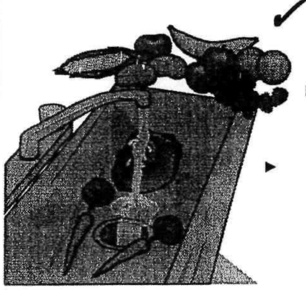
✓ **If elevated levels of arsenic are found in the soil of gardens in the VBI-70 area, is it safe to eat home-grown fruits and vegetables?**

Yes, it is safe to eat fruits and vegetables that are grown in your garden in the VBI-70 area. It is not likely that eating home-grown fruits and vegetables will be harmful.

✓ **If there are elevated levels of arsenic in the soil, will arsenic also be found in the fruits and vegetables?**



Fruits and vegetables that are grown in soils with any level of arsenic will take up a small amount of arsenic through their roots. But the amount of arsenic that might be taken into your body from eating these fruits and vegetables is far below the levels that are known to cause illness.



✓ **Are there healthy ways to garden?**

Yes, the following tips are healthy practices for all gardeners:

- Wash your hands after working in the garden and before handling fruits and vegetables.
- Wash fruits and vegetables, especially low-growing vegetables like collard greens, spinach, and lettuce that are grown in your garden.

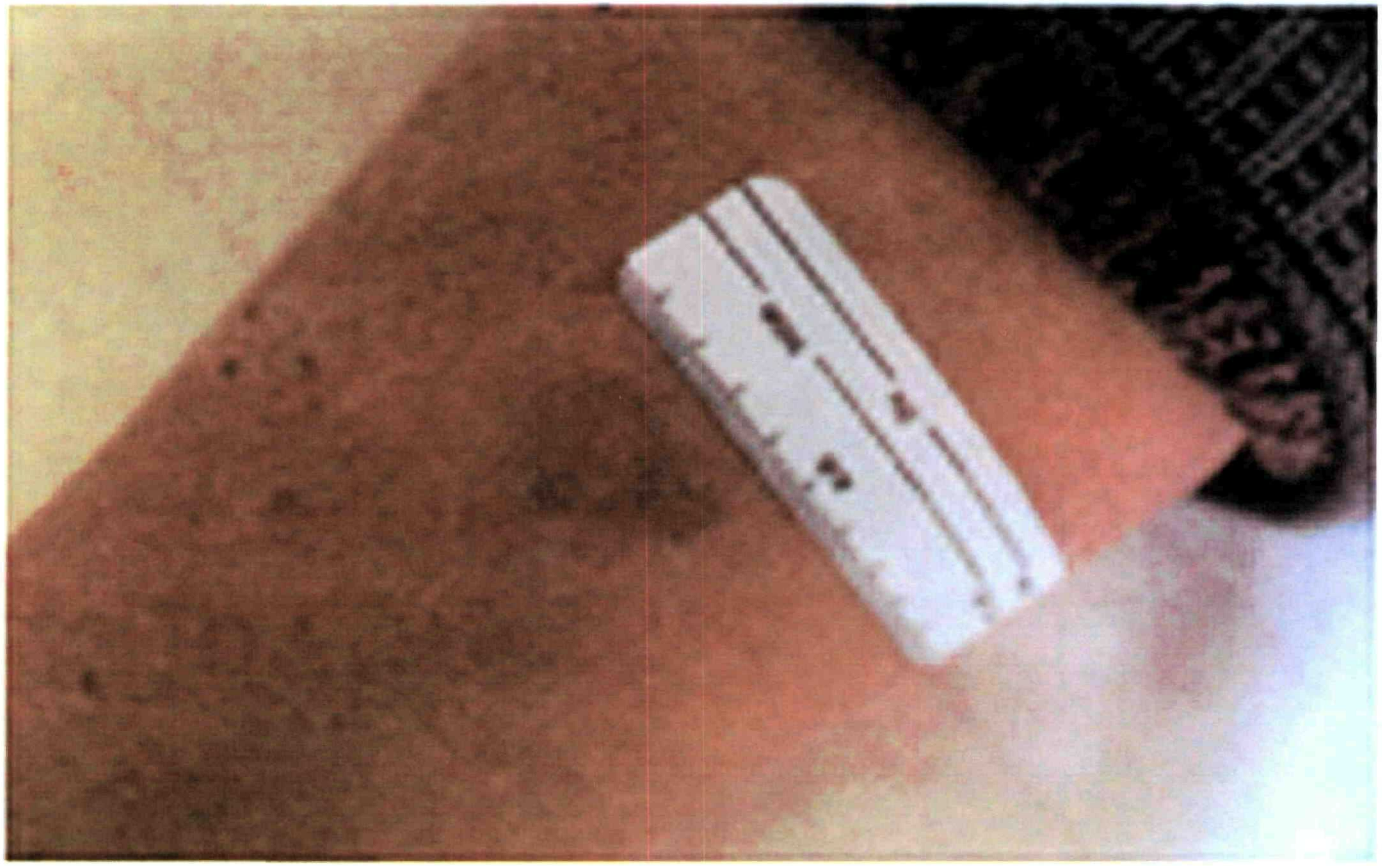
For More Information . . .

For more information about gardening and other health studies in your area, you may contact:

David Mellard	*Lourdes Rosales-Guevara*	*Jane Mitchell*
ATSDR	ATSDR (Spanish speaking)	CDPHE
1-888-42-ATSDR	1-888-42-ATSDR	(303) 692-2644

Appendix G

Photographs of hyperpigmentation and keratosis



Hyperpigmentation

Keratosis

Severe Keratosis

Skin Cancer

Appendix H

ATSDR's Quantitative Approach for Estimating Arsenic Doses in Children with Soil-Pica Behavior and in Children with Typical Soil Intake

ATSDR's Quantitative Approach For Estimating Arsenic Doses in Children

Soil-Pica children

To evaluate exposure to arsenic in soil for children with soil-pica behavior, ATSDR used the following formula:

Estimated exposure dose in soil-pica children =

$$\frac{\text{(Arsenic concentration in soil) x (intake rate of soil) x (bioavailability factor) x (exposure frequency) (1/1,000,000 kilogram/milligram)}}{\text{body weight}}$$

The concentration in soil is the estimated maximum discrete level of arsenic based on the formula y = 6.399x where x is the maximum composite level and y is the maximum, discrete arsenic level (see Table 2 in the section *Arsenic in the VBI70 Study Area.*) ATSDR used a range of soil intakes for a soil-pica episode from 600 mg to 5,000 mg per day. The bioavailability factor for soil from the VBI70 site is estimated to range from 40 to 60%, while the body weight of a 1-year old Hispanic child is estimated to be 11 kg.[26] The exposure frequency ranged from 1 day (a 1-time event) to 3 days out of 7, or 3/7. The term 1/1,000,000 is a conversion factor so that units cancel correctly. Table H-1 shows the range of doses for a 1-year-old soil-pica child at the property with the highest soil arsenic contamination based on Phase III data.

Table H-1.
Comparison of Estimated Arsenic Doses
Varying Bioavailability and Frequency of Exposure for Soil-pica Children

Soil Intake mg	1-Time Episode Estimated Arsenic Dose 40% bioavailability mg/kg/day	1-Time Episode Estimated Arsenic Dose 60% bioavailability mg/kg/day	3 Days per Week Estimated Arsenic Dose 40% Bioavailability mg/kg/day	3 Days per Week Estimated Arsenic Dose 60% Bioavailability mg/kg/day
600	0.11	0.16	0.05	0.07
1000	0.19	0.27	0.08	0.11
3000	0.56	0.79	0.24	0.34
5000	0.93	1.32	0.34	0.57

[26] ATSDR is in the process of evaluating an EPA swine study to determine if EPA's suggested bioavailability of 42% is appropriate.

The following examples show a sample calculation to estimate the dose if a 1-year-old soil-pica child lives at the most highly contaminated yard and exhibits soil-pica behavior in a part of the yard with the highest arsenic contamination.

4748 mg arsenic/kg soil x 5,000 mg soil/day x 0.6 x 1 x 1/1,000,000 / 11 kg = 1.3 mg/kg/day

As can be seen from Table H-1, a wide range of arsenic doses are possible for a 1-time soil-pica episode (0.1 mg/kg/day to 1.3 mg/kg/day) depending upon the amount of soil eaten and the bioavailability. The estimated doses are obviously lower should the child eat soil from a less contaminated part of the yard. A range of estimated arsenic doses is also possible for habitual soil-pica episodes (0.05 to 0.57 mg/kg/day), again depending upon how much soil is eaten and the assumed frequency of 3 times per week.

As mentioned previously in the text, about 200 children live at the 650 or so properties that are a concern should a soil-pica child eat 5,000 mg soil. Of these 200 children, about 10 to 40 children might have a soil-pica episode some time during their preschool years.

Children with typical soil intake levels

ATSDR estimated the range of arsenic exposures for preschool children who live in the VBI70 study area and who have typical soil intakes. Most preschool children have soil intake levels that range from 10 mg to over 200 mg each day. Recently, a study was reported concerning soil ingestion in preschool children who live near a hazardous waste site in Anaconda, Montana. The results of this 1-week study showed an average soil ingestion rate of 31 mg soil each day. Ninety-five out of one hundred children had an average soil intake below 141 mg each day, and the highest reported average soil-ingestion was 219 mg each day. What is of additional note in this study was that the authors found a soil-pica child and estimated soil ingestion to be between 600 and 700 mg (Stanek and Calabrese 2000).

When evaluating soil ingestion in children, one should remember that most children ingest small amounts of soil while a small group of children ingest larger amounts of soil. For the VBI70 site, ATSDR used 30 mg soil ingested per day to estimate arsenic exposure for the typical preschool child and 200 mg soil ingestion per day to estimate arsenic exposure for preschool children at the upper end of typical soil intake. In addition, ATSDR looked at exposures for 1-year-old children who weighed 11 kilograms (approximately 25 pounds) as well as the average weight of a 1 to 6 year old child (16.6 kilograms or approximately 37 pounds). As children grow older their weight increases, which means that their exposure to contaminants in soil decreases based on body weight. Estimating exposure for all these age groups gives a wide range of dose estimates within each age group and between age groups.

ATSDR used the same basic formula to estimate acute arsenic doses for children with typical soil intake levels using the following parameters:

- maximum and average arsenic level in the property;
- an exposure frequency of one because exposure occurs every day;
- soil intake levels of 30 mg/day and 200 mg/day; and
- body weights of 11 and 16.6 kg.

Table H-2 shows the estimated dose for a 1-time exposure to the maximum arsenic levels in soil to determine if children with typical soil intake are at risk of acute effects from exposure to arsenic. While estimates for 16.6 kg children were conducted, only dose estimates for 11 kg children are provided here.

Table H-2.
Comparison of Estimated Arsenic Doses
Varying Different Factors in the Equation to Estimate Dose
For Children with Typical Soil Intake

Arsenic Concentration in Soil ppm	Soil Intake mg/day	Estimated Dose at 40% Bioavailability and 11 kg Body Weight mg/kg/day	Estimated Dose at 60% Bioavailability and 11 kg Body Weight mg/kg/day	Provisional Acute MRL mg/kg/day
4748 (Max)	30	0.005	0.008	0.005
4748 (Max)	200	0.04	0.05	0.005
759 (Average)	30	0.001	0.001	0.005
759 (Average)	200	0.006	0.008	0.005

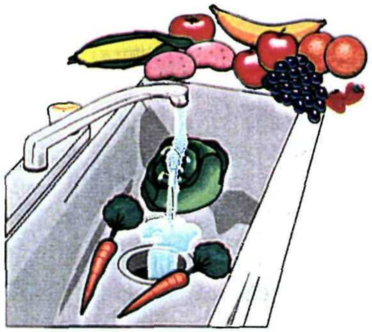
From Table H-2, the 1-time estimated dose exceeds ATSDR's provisional, acute MRL only for children with soil intakes approaching 200 mg while children with soil intakes around 30 mg are below ATSDR's provisional acute MRL. Only those children with intakes around 200 mg a day, who live at properties with average arsenic levels around 760 ppm, and who ingest soil from the most contaminated part of a yard have arsenic exposure that are likely to cause the transient effects of nausea, vomiting, diarrhea, and facial swelling. Most children with typical soil intakes (about 30 mg a day) are not at risk for acute harmful effects.

Appendix I

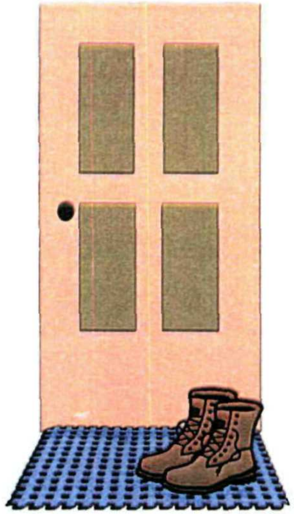
Information Sheet: Ways to Protect Your Health

Ways to protect your health

By keeping dirt from getting into your house and into your body



Wash and peel all fruits, vegetables, and root crops

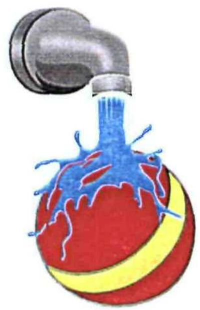


Wipe shoes on doormat or remove shoes

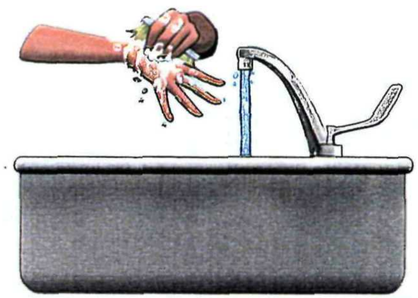
Don't eat food, chew gum, or smoke when working in the yard

Damp mop floors and damp dust counters and furniture regularly

Wash dogs regularly



Wash children's toys regularly



Wash children's hands and feet after they have been playing outside

Appendix J

ATSDR Environmental Terms

ATSDR Plain Language Glossary of Environmental Health Terms

Absorption: How a chemical enters a person's blood after the chemical has been swallowed, has come into contact with the skin, or has been breathed in.

Acute Exposure: Contact with a chemical that happens once or only for a limited period of time. ATSDR defines acute exposures as those that might last up to 14 days.

Additive Effect: A response to a chemical mixture, or combination of substances, that might be expected if the known effects of individual chemicals, seen at specific doses, were added together.

Adverse Health Effect: A change in body function or the structures of cells that can lead to disease or health problems.

ATSDR: The Agency for Toxic Substances and Disease Registry. ATSDR is a federal health agency in Atlanta, Georgia that deals with hazardous substance and waste site issues. ATSDR gives people information about harmful chemicals in their environment and tells people how to protect themselves from coming into contact with chemicals.

Background Level: An average or expected amount of a chemical in a specific environment. Or, amounts of chemicals that occur naturally in a specific environment.

Bioavailability: How much of a chemical enters a human's body from the environment, usually present as percent bioavailable or percent absorb. An example is the percent of chemical that is absorbed across the gut once ingested.

Cancer: A group of diseases which occur when cells in the body become abnormal and grow, or multiply, out of control

Carcinogen: Any substance shown to cause tumors or cancer in experimental studies.

CERCLA: See Comprehensive Environmental Response, Compensation, and Liability Act.

Chronic Exposure: A contact with a substance or chemical that happens over a long period of time. ATSDR considers exposures of more than one year to be *chronic*. EPA considers chronic exposure to from 10 percent of a lifetime to lifetime, for instance, from 7 to 70 years for humans.

Completed Exposure Pathway: See **Exposure Pathway**.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): **CERCLA** was put into place in 1980. It is also known as **Superfund.** This act concerns releases of hazardous substances into the environment, and the cleanup of these substances and hazardous waste sites. ATSDR was created by this act and is responsible for looking into the health issues related to hazardous waste sites.

Concern: A belief or worry that chemicals in the environment might cause harm to people.

Concentration or Level: How much or the amount of a substance present in a certain amount of soil, water, air, or food.

Contaminant: See **Environmental Contaminant.**

Dermal Contact: A chemical getting onto your skin. (see **Route of Exposure**).

Dose: The amount of a substance to which a person may be exposed, usually on a daily basis. Dose is often explained as "amount of substance(s) per body weight per day".

Dose Response: The relationship between the amount of exposure (dose) and the change in body function or health that result.

Duration: The amount of time (days, months, years) that a person is exposed to a chemical.

Environmental Contaminant: A substance (chemical) that gets into a system (person, animal, or the environment) in amounts higher than that found in **Background Level**, or what would be expected.

Environmental Media: Usually refers to the air, water, and soil in which chemicals of interest are found. Sometimes refers to the plants and animals that are eaten by humans. **Environmental Media** is the second part of an **Exposure Pathway**.

U.S. Environmental Protection Agency (EPA): The federal agency that develops and enforces environmental laws to protect the environment and the public's health.

Epidemiology: The study of the different factors that determine how often, in how many people, and in which people will disease occur.

Exposure: Coming into contact with a chemical substance.(For the three ways people can come in contact with substances, see **Route of Exposure.**)

Exposure Assessment: The process of finding the ways people come in contact with chemicals, how often and how long they come in contact with chemicals, and the amounts of chemicals with which they come in contact.

Exposure Pathway: A description of the way that a chemical moves from its source (where it began) to where and how people can come into contact with (or get exposed to) the chemical.

ATSDR defines an exposure pathway as having 5 parts:

1. Source of Contamination,
2. Environmental Media and Transport Mechanism,
3. Point of Exposure,
4. Route of Exposure, and
5. Receptor Population.

When all 5 parts of an exposure pathway are present, it is called a **Completed Exposure Pathway**. Each of these 5 terms is defined in this Glossary.

Frequency: How often a person is exposed to a chemical over time; for example, every day, once a week, twice a month.

Hazardous Waste: Substances that have been released or thrown away into the environment and, under certain conditions, could be harmful to people who come into contact with them.

Health Effect: ATSDR deals only with **Adverse Health Effects** (see definition in this Glossary).

Indeterminate Public Health Hazard: The category is used in Public Health Assessment documents for sites where important information is lacking (missing or has not yet been gathered) about site-related chemical exposures.

Ingestion: Swallowing something, as in eating or drinking. It is a way a chemical can enter your body (See **Route of Exposure**).

Inhalation: Breathing. It is a way a chemical can enter your body (See **Route of Exposure**).

LOAEL: Lowest Observed Adverse Effect Level. The lowest dose of a chemical in a study, or group of studies, that has caused harmful health effects in people or animals.

MRL: Minimal Risk Level. An estimate of daily human exposure – by a specified route and length of time -- to a dose of chemical that is likely to be without a measurable risk of adverse, noncancerous effects. An MRL should not be used as a predictor of adverse health effects.

NPL: The National Priorities List. (Which is part of **Superfund**.) A list kept by the U.S. Environmental Protection Agency (EPA) of the most serious, uncontrolled or abandoned hazardous waste sites in the country. An NPL site needs to be cleaned up or is being looked at to see if people can be exposed to chemicals from the site.

NOAEL: No Observed Adverse Effect Level. The highest dose of a chemical in a study, or group of studies, that did not cause harmful health effects in people or animals.

No Apparent Public Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where exposure to site-related chemicals may have occurred in the past or is still occurring but the exposures are not at levels expected to cause adverse health effects.

No Public Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where there is evidence of an absence of exposure to site-related chemicals.

PHA: Public Health Assessment. A report or document that looks at chemicals at a hazardous waste site and tells if people could be harmed from coming into contact with those chemicals. The PHA also tells if possible further public health actions are needed.

Population: A group of people living in a certain area; or the number of people in a certain area.

PRP: **P**otentially **R**esponsible **P**arty. A company, government or person that is responsible for causing the pollution at a hazardous waste site. PRP's are expected to help pay for the clean up of a site.

Public Health Assessment(s): See **PHA**.

Public Health Hazard: The category is used in PHAs for sites that have certain physical features or evidence of chronic, site-related chemical exposure that could result in adverse health effects.

Public Health Hazard Criteria: PHA categories given to a site which tell whether people could be harmed by conditions present at the site. Each are defined in the Glossary. The categories are:

1. Urgent Public Health Hazard
2. Public Health Hazard
3. Indeterminate Public Health Hazard
4. No Apparent Public Health Hazard
5. No Public Health Hazard

Reference Dose (RfD): An estimate, with safety factors (see **safety factor**) built in, of the daily, life-time exposure of human populations to a possible hazard that is <u>not</u> likely to cause harm to the person.

Route of Exposure: The way a chemical can get into a person's body. There are three exposure routes:
- breathing (also called inhalation),
- eating or drinking (also called ingestion), and
- or getting something on the skin (also called dermal contact).

Safety Factor: Also called **Uncertainty Factor**. When scientists don't have enough information to decide if an exposure will cause harm to people, they use "safety factors" and formulas in place of the information that is not known. These factors and formulas can help determine the amount of a chemical that is <u>not</u> likely to cause harm to people.

SARA: The Superfund Amendments and Reauthorization Act in 1986 amended CERCLA and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from chemical exposures at hazardous waste sites.

Source (of Contamination): The place where a chemical comes from, such as a landfill, pond, creek, incinerator, tank, or drum. Contaminant source is the first part of an **Exposure Pathway**.

Special Populations: People who may be more sensitive to chemical exposures because of certain factors such as age, a disease they already have, occupation, sex, or certain behaviors (like cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Statistics: A branch of the math process of collecting, looking at, and summarizing data or information.

Soil Ingestion: Soil ingestion is the consumption of soil. Soil ingestion may result from various behaviors including, but not limited to, mouthing, contacting dirty hands, eating dropped food, and consuming soil directly.

Soil-pica: Soil-pica is the recurrent ingestion of unusually high amounts of soil (i.e., on the order of 600 to 5,000 milligrams or more). While pica activity has a habitual component to the behavior, ATSDR is also concerned about 1-time soil ingestion events where unusually high amounts of soil are ingested. Groups at particular risk of soil-pica include children aged 6 years and younger and developmentally delayed individuals.

Superfund Site: See **NPL**.

Survey: A way to collect information or data from a group of people (**population**). Surveys can be done by phone, mail, or in person. ATSDR cannot do surveys of more than nine people without approval from the U.S. Department of Health and Human Services.

Synergistic effect: A health effect from an exposure to more than one chemical, where one of the chemicals worsens the effect of another chemical. The combined effect of the chemicals acting together are greater than the effects of the chemicals acting by themselves.

Toxic: Harmful. Any substance or chemical can be toxic at a certain dose (amount). The dose is what determines the potential harm of a chemical and whether it would cause someone to get sick.

Toxicology: The study of the harmful effects of chemicals on humans or animals.

Uncertainty Factor: See **Safety Factor**.

Urgent Public Health Hazard: This category is used in ATSDR's Public Health Assessment documents for sites that have certain physical features or evidence of short-term (less than 1 year), site-related chemical exposure that could result in adverse health effects and require quick intervention to stop people from being exposed.

Appendix K

ATSDR's Letter to EPA About Community Concerns

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Agency for Toxic Substances
and Disease Registry
Atlanta GA 30333

March 24, 1999

Ms. Bonnie Lavelle, RPM
US EPA Region VIII
8EPR-RP
999 18th Street, Suite 500
Denver, CO 80202

Re: Community Concerns

Dear Ms. Lavelle:

As you know, the Agency for Toxic Substances and Disease Registry (ATSDR) has started activities associated with its public health assessment of the Vasquez Boulevard site (VBI70). One of the major components of the public health assessment is to identify and address community health concerns. To date, the VBI70 health team has met and conducted numerous conference calls with representatives from various neighborhood organizations around the site. The VBI70 health team consists of representatives from ATSDR, Colorado Department of Public Health and Environment, Denver Department of Environmental Health, and community representatives. Community representatives on the VBI70 health team have told us many of their concerns.

As we discussed with you earlier, some concerns that the community representatives have expressed are outside of ATSDR's responsibilities in the Superfund process. We have informed the community representatives that when concerns come up that are more appropriately answered by other agencies, we will convey those concerns to the appropriate agency or organization.

Listed below are the concerns that have been raised that would best be answered by the EPA. Our responses to the community representatives on certain concerns are in italics.

6. Community representatives expressed a need to understand the sampling methods the EPA used at the VBI70 site. Specifically, they want to understand the difference between a composite versus an average, and how the difference between the two is used in risk assessment. Community representatives also want to know why the EPA did not sample for cadmium and zinc.

   ATSDR realizes that while some sampling was done for cadmium and zinc (for example, some of the confirmatory samples measured for cadmium and zinc), the community representatives did not understand the EPA's previous explanations.

7. Community representatives want to know the reasons certain houses were deleted from the list of houses for an emergency cleanup?

   We discussed with the community representatives the EPA's explanation and handout given during the January 28 working group meeting. During our discussion with the *community representatives, we realized that they had concerns about the selection of properties for removal activities and related topics. For instance, community representatives disagreed with the way houses were selected for sampling. Other issues that were raised included questions about the sampling approach, door-to-door canvassing, testing before action levels are set, and Phase III samples. We suggested to the community representatives that they discuss the issues with you.*

I think the community representatives understand the EPA's reasons for selecting homes for removal activities but may still disagree with those reasons. In addition, they have other concerns related to the selection of homes for removal as well as sampling and timing issues. EPA staff members may want to talk to the community representatives again about the issues mentioned to have a better understanding of their concerns and questions.

8. Community representatives want to know beforehand the meanings of environmental and health terms that might be used during work group discussions. During our discussions with them, they did not specify any terms in particular, although I remember them mentioning MRLs and RfDs as examples during work group meetings.

   I have agreed to put together a short dictionary of scientific terms that ATSDR might use. We are also passing the concern onto you since the EPA has its own scientific terms and jargon.

9. Community representatives expressed a need to better understand the EPA's risk assessment process. They also wish to have the explanation in writing.

As we continue to receive concerns related to the EPA, we will forward them to you. Thank you for your attention to these issues. If I can provide you with additional information, please contact me at (404) 639-0639.

Sincerely,

David Mellard, Ph.D.
Toxicologist
Division of Health Assessment and Consultation
cc:
Ms. Joan Hooker
Mr. Anthony Thomas
Ms. Sandy Douglas
Ms. Melissa Muñoz
Ms. Rosemary Riley
Ms. Lorraine Granado
Ms. Barbara O'Grady
Ms. Celia VanDerLoop
Ms. Susan Muza